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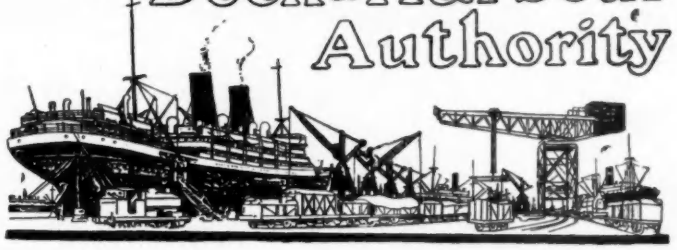

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Editorial Comments

The Port of Liverpool.

In the March 1948 issue of this Journal, we published an article describing the repairs to the war damaged Gladstone-Hornby Lock, which connects the two docks of those names, and enables vessels using the Gladstone entrance to pass to all the other docks comprising the Northern Group of the Docks of Liverpool.

We are now privileged to present in this issue, a description of what is known as the Langton-Canada Improvement Scheme, sanctioned by Act of Parliament in 1945, on which work can proceed now that the repair of the above-mentioned lock has been completed.

For the benefit of our overseas readers, who may not be conversant with the position of the Port of Liverpool in relation to other ports, we should mention that it is one of the chief ports of the world, and ranks, after London, as the second largest port of Great Britain. Its imports, in value, are roughly half, and its exports are very nearly equal to, those of the Port of London. The bulk of the export trade is in manufactured goods, the two main groups being yarn and textiles, and metals and machinery, with chemicals comprising an important item in the miscellaneous group. Imports consist chiefly of food, drink and tobacco and the raw materials used in many industries. In the former group, grain for flour milling, and tobacco; and in the latter group, tin ore, seeds and nuts for oil, timber, hides and skins, are all manufactured in the district. The principal import is cotton, which is manufactured in the adjoining Manchester region, and is then re-exported in the form of yarns and textiles, as mentioned above.

It was found during the last war, in spite of the handicaps of war conditions in the port, that the docks were able to handle volumes of cargo, diverted from London and other ports, greatly in excess of those dealt with in the pre-war period. Consequently, the Mersey Docks and Harbour Board in 1943, considering all aspects of probable post-war conditions, decided that an intelligent policy of modernisation, rather than an extension of the existing docks, would better serve the interests of port users, and at the same time provide, for some years to come, a substantial margin in handling facilities.

This policy, with provision for future extension of the docks, was accordingly incorporated in the plan for Mersey-side, produced by the Ministry of Town and Country Planning in 1945, in which year Parliamentary sanction was also obtained. Excerpts from the Report were published in the May 1945 issue of this Journal.

The scheme is in accordance with the Government's policy, in the present economic conditions, of limiting capital expenditure on all except the most essential works. Moreover it shows no tendency towards the uneconomic policy of attempting to attract certain classes of trade from other ports which are already equipped to deal with them efficiently.

The most important part of the Improvement Scheme is the construction of a large river entrance lock which eliminates two smaller locks and the obsolescent tidal basin, all constructed some 60 to 100 years ago. Of particular interest is the choice, following Continental practice, of sliding caissons for operating the lock, in lieu of mitre gates which are more usual in this country. The steps taken, by means of a ship caisson and emergency stops, to provide for pumping out the lock for inspection and repair, are also worthy of note.

Another interesting feature in the design of the lock is the interchangeability of the caissons, and the extremely useful facility provided for utilising the middle caisson chamber as a dry dock for the repair of any of the lock caissons, while at the same time retaining the full working length of the lock in use.

With such drastic alterations to the existing layout of the site entailed by the scheme in general, it is obvious that the sequence of constructional work has necessitated some careful planning, in order that normal shipping and docking operations will not be unduly interfered with. Fortunately, the foundation stratum is considered to be good, i.e., rock of hard quality at a reasonable depth, and the lock and quay walls, as might be expected in such circumstances, will be of the full gravity type. However, the overburden of sand, gravel and deposits of peat, silt and fine sand sometimes met with over the site, coupled with the 34-ft. range of tide, have always set problems of some difficulty in the Liverpool Docks, in respect to temporary dams and trench excavations. The methods and types decided upon are therefore of special interest.

The whole modernisation scheme involving an expenditure of £10,000,000 and six years of work, is probably the largest and most important post-war programme of dock reconstruction which, up to the present, has been attempted in this country. We are indebted to Mr. L. Leighton, Engineer-in-Chief to the Mersey Docks and Harbour Board, for enabling our contributors to produce an article which, we feel sure, will be studied with interest by all engaged in dock engineering.

The International Navigation Congress.

Following the publication in our two previous issues of the Papers dealing with the Inland Navigation Section, our readers will find in this number an abridged version of the General Report dealing with Question One of the Ocean Navigation Section of the 17th International Navigation Congress which was held in Lisbon in September last. It was intended to deal with both Questions 1 and 2, but owing to space limitations, we have been compelled to defer consideration of Question 2 until next month.

The subject of the First Question—Regularisation and Improvement of Estuaries—is probably of the most general interest. Mr. Schreck, within the limits of a single short report, was naturally quite unable to reproduce the mathematical and other scientific

Editorial Comments—continued

data presented by the authors. Nevertheless the Report constitutes a comprehensive review and summary of the papers submitted.

The hydraulics of conservancy or river engineering is not an exact science, although such data as range and speed of tides, directions of currents, dimensions of waves, etc., can be observed and measured, to mention only a few of the phenomena which cause the problems with which the engineer is confronted. As a consequence, he is not often able to translate by mathematics his observations and measurements into exact forecasts of the results which will be likely to be induced by the carrying out of his projects, either in the way of dredging or training structures.

The engineer can, however, supplement his own experience with that recorded by other observers and workers in this field of research, where he will find instances in which problems more or less similar, but never exactly uniform have been solved successfully. Herein lies the benefit of such papers as have been submitted to the Congress upon the problems of estuary regularisation.

Cathodic Treatment for Corrosion.

Considerable interest has been aroused by references in the article on the Port of Long Beach, which appeared in our issue of last June, to Cathodic treatment, and to Monotube piling.

Full details of the latter have not yet been obtained, but in respect to the former, we have been able to secure some additional information from the Author of the article as to the present stage of the installation of the Cathodic system.

It appears that the application of Cathodic treatment for the prevention of metal corrosion in marine structures in America has not reached the degree of finality which was implied in the article, but experiments at Long Beach have progressed to an advanced stage and seem likely to be resolved shortly. In all, ten groups of circuits have been laid out covering 2,500-ft. of water frontage together with those portions of the installations which became necessary as the development of the steel sheet piling and wharf structures progressed.

It is however proposed to instal two or more different types of systems and to watch them for some time, including the recording of instrumental data as to current flow, potentiality, etc., before the balance of the Cathodic treatment installation is proceeded with.

In America the protection of buried pipe lines by Cathodic methods is being successfully applied on a large scale and basically the system seems to be just as simple for the protection of steel piling and similar structures situated in water.

Observations lead to the belief that properly divided electric circuits can be set up, into which can be sent, through the medium of rectifiers, a proper amount of direct current electricity in such a manner as to establish a positive flow of electricity from an anode towards the steel which it is desired to protect. The real problems arise in the determination of just what amount of electricity to utilise for a given type of structure under given conditions, together with the type of anode and location of them to produce the best results.

We are promised a detailed account of the experiments and tests and the results obtained, as soon as some degree of finality and decision has been reached as to the form and type of Cathodic system to be installed at Long Beach. Meanwhile we are privileged to publish excerpts from a lecture upon the subject delivered early this year by Mr. W. H. J. Vernon before the Royal Society of Arts.

The postponement of natural decay and the preservation from corrosion and deterioration of materials of construction and in particular of iron, steel and timber, has exercised the minds of scientists and engineers for a long time past, and a considerable amount of work has been carried out in this field of research. It must be admitted, however, that we are far from having achieved finality.

Mr. Vernon, in his lecture, deals at length with the various methods of preservation of ferrous materials, and space alone prevents us publishing his remarks in full. We hope, however, that what has been reproduced elsewhere in this issue will prove of interest to readers as a basis for possible further study of the work of Mr. Vernon and other investigators in this field, a bibliography of which is given in the Journal of the Royal Society of Arts, No. 4798, Volume XCVII, 1st July, 1949.

We are of opinion that the probable ultimate solution of the problem of steel corrosion lies in a modification of the metal itself by the use of corrosion resistant alloys. Indeed, in this branch of study of the question, some considerable success on a commercial basis has been attained already in the United Kingdom—a bascule bridge of alloy steel having been built at the end of last year, at the Port of Sunderland. The particular alloy used in this case—aluminium—resulted in a saving in weight of steel together with little propensity to corrode.

In the meantime and for many years to come, we are faced with the problem of preservation of structures already existing, and it seems that, apart from the advantages of the monetary savings effected, it is at last being realised that supplies of basic materials are by no means inexhaustible and therefore must be conserved, and that thoughtless exploitation and profligacy in their use must be avoided.

The perfection of preservation methods is thus extremely desirable and in the case of steel, looking into the distant future, might even become a pressing economic necessity, unless some form of non-corrosive alloy steel can be manufactured universally in sufficient quantity, or alternatively, fresh workable sources of supply of mineral ores are discovered.

Preservation of Timber.

In the realm of timber many of the above remarks are equally applicable and it will be remembered that we had something to say in regard to timber and its conservation in our June issue.

At a time when supplies of timber are short and prices are high, and the economic position of the country is so precarious, the need to impress upon the users of timber the value of preservation treatment is even more urgent, and may be regarded as a national necessity. We are pleased to learn therefore that the British Wood Preserving Association, founded in 1930, is undertaking a new campaign for the scientific and economic usage of timber and preservatives for it. The Association acting in liaison with the Timber Development Association apparently will remain an impartial body and will be concerned not so much with the varying trade aspects of the wood preserving industry, but rather with the proper application of proved preservatives.

The advertised objectives of the Association appear to be to the best advantage of those interested in timber, whether they be concerned with buying and selling timber, or with the various methods of wood preservation, or as consumers.

It is to be hoped that improvement in the economic and efficient use of timber and its preservation will be effected by the Association, as this would prove beneficial to the country as a whole.

An American Suction Dredger.

Elsewhere in this issue we produce an account of the latest dredger built for the United States Corps of Engineers. It will be the largest in the world, somewhat exceeding in dimensions the "Leviathan" and the ill-fated "Fu-shing." It is 500-ft. long between perpendiculars, its main pumps have a water output of 127,000 American gallons per minute and its loaded cruising speed is 15.5 miles per hour and it dredges at 3 miles per hour.

Whilst the general arrangement is the twin side pipe system, which is now the American standard for trailing dredging practice, there are many novel features. The system of pumping excess water from the loaded hoppers advocated by Mr. J. A. S. Rolfe, has been incorporated and the very ingenious method devised by Mr. R. H. Hoffman for extracting the occluded gases from the mud greatly helps the dredging of this material. There is an 800 yard hopper, and power is produced on the turbo-generator system.

The previous largest vessel in New York harbour, the "General Goethals," has evidently proved so successful that the American Army Engineers feel justified in "going one better." There are unfortunately few cases in the British Isles where this type of dredger can be used effectively but in the Dominions, Colonies and elsewhere abroad there are many opportunities for drag suction operation and it is to be hoped that some British designers will produce similar vessels or show that their own systems are equally effective.

The Port of Liverpool

Details of Improvement Scheme for the North Docks

By R. A. STEPHENSON, B.Eng., A.M.I.C.E.,
and R. N. NORFOLK, M.B.E., A.M.I.C.E.

Introduction

TO keep the docks and facilities at Liverpool and Birkenhead abreast of modern shipping requirements is the constant concern of the Mersey Docks and Harbour Board. It is axiomatic that the facilities provided should ensure the smooth flow of goods to and from the quayside and that free movement of ships should be possible between the river and the docks at all states of the tide, thereby enabling a quick turn-round to be made. To achieve this end, the Board find it necessary, from time to time, to spend large sums of money, either on constructing new docks on undeveloped sites, or on reconstructing and improving the existing docks. For the time being, the Board have decided that the interests of the users of the Port will be the better served by the improvement of the existing docks, rather than the extension of the system by the construction of new docks. The subject of this article is the Langton-Canada Improvement Scheme, the latest of these capital works, for which Parliamentary sanction was obtained in 1945.

Early this year (1949), the Board decided that the first stage, covering about two years' work, should be put in hand on the completion of certain other works, then still in progress; these included the repairs to the Gladstone-Hornby Lock,[1] damaged during the war, and the new Waterloo River Entrance lock, situated in the central docks, for use by coastal shipping.

The most important part of the new scheme is the construction of a large river entrance lock, and before proceeding further, it will be helpful to give a brief description of the docks that will benefit from it.

The Existing North Docks

The Liverpool North Docks [see Fig. 1] embrace the largest group of deep-water docks in the port. These docks extend along the Liverpool and Bootle river front for about three miles, and, except for the Gladstone Docks, opened in 1927, were all constructed between 1845 and 1884. The new entrance is being constructed primarily to serve these older docks, which extend from Sandon at the south end, to Hornby at the north end of the group; the Gladstone Docks will benefit also, though indirectly, as, should the excellent Gladstone River Entrance lock be closed for repairs, there would be a good alternative entrance.

As a counterpart to the deepening of the channel across the Mersey Bar in the 1890's, additions and improvements were made to the Sandon, Huskisson and Canada Docks by the construction of branch docks, the lengthening and deepening of Canada Lock, the lengthening of certain quays and by the deepening of existing docks. The deepening was effected by lowering the foundation levels of the quay walls by underpinning executed under the cover of cofferdams, and afterwards dredging to the new bottom. A further instalment of additions and improvements was carried out between 1904 and 1908, when Brocklebank Dock was deepened, more branch docks constructed and all the inter-dock passages between Alexandra and Canada Docks were widened and deepened.

The effective depth of the water in the North system was also increased by pumping from the river to maintain a minimum level in the docks, irrespective of the prevailing high-water level. At the present time the minimum impounded level corresponds to high water of spring tides, and, over neaps, access to the system is by locking at all states of tide.

The group, extending from Sandon Half-Tide Dock to Hornby Dock, comprises over 37,000 linear feet of deep-water berths and six graving docks, ranging in length from 450 to 925 ft.

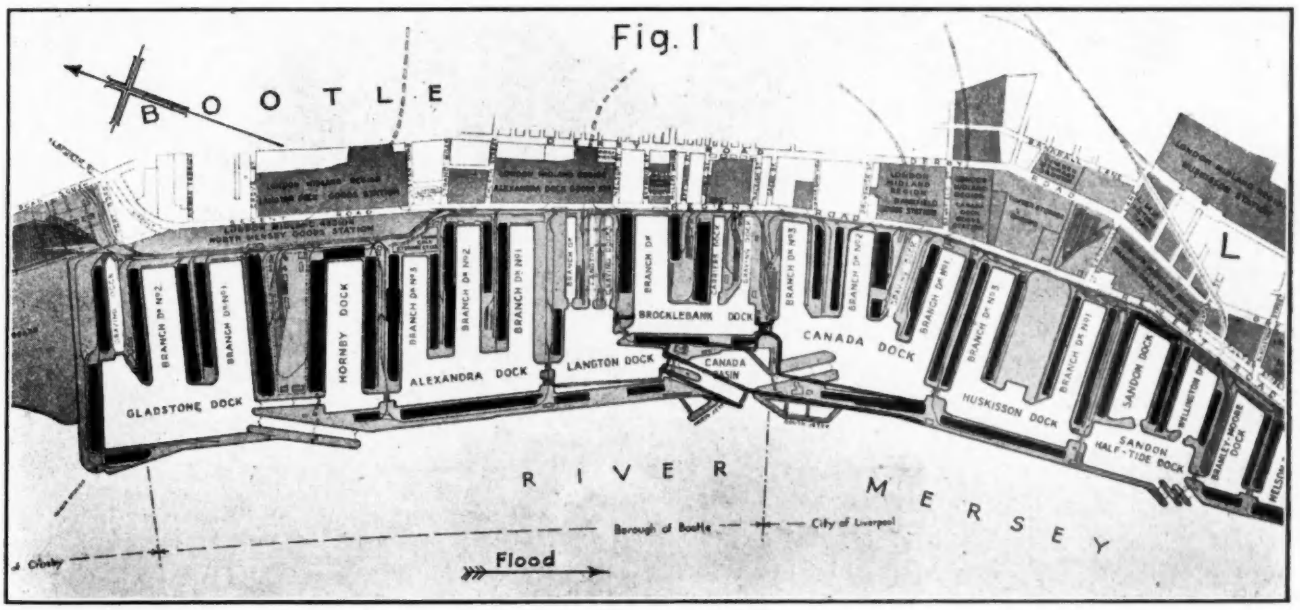
The Need for the Improvements

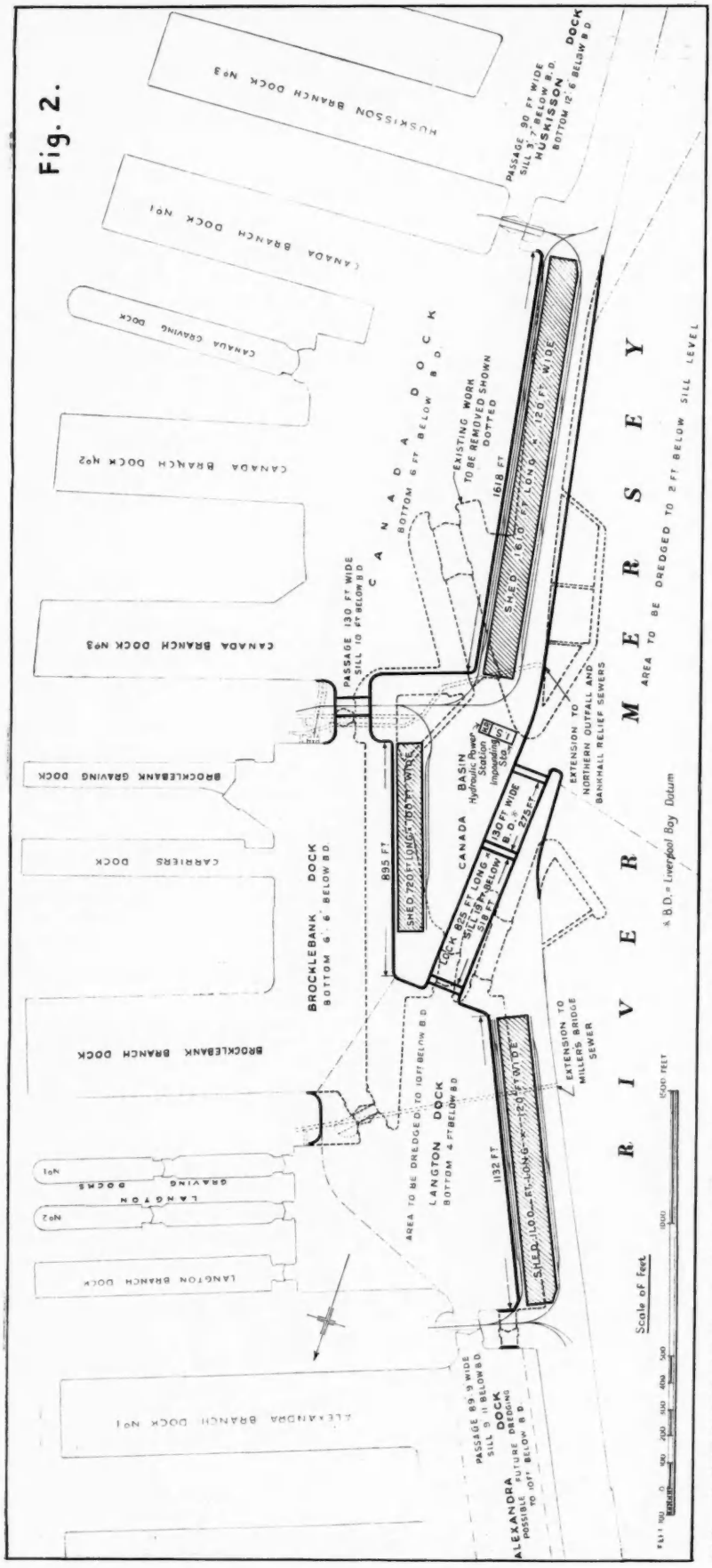
At present the only deep-water access from the river to this important system is through the Gladstone-Hornby Lock, at the extreme north end, via Gladstone Dock and River Entrance. Ships using this route can depend on thirty feet of water for about eight hours each tide.

The other entrances from the river are less useful. The Sandon River Entrances, at the extreme south end, are non-locking entrances and can be used close to high water only. Delay is incurred whenever locking is necessary, as this must be effected by means of Sandon Half-Tide Dock, a basin having an area of 14 acres, more than four times that of the Gladstone River Entrance lock.

(1) See March, 1948, "Dock and Harbour Authority."

Fig. 1




HUSKISSON BRANCH DOCK No3
CANADA BRANCH DOCK No1
CANADA GRAVING DOCK
CANADA BRANCH DOCK No2
CANADA BRANCH DOCK No3
BROCKLEBANK GRAVING DOCK
CARRIERS DOCK
BROCKLEBANK BRANCH DOCK
LANGTON GRAVING DOCKS
LANGTON BRANCH DOCK
ALEXANDRA BRANCH DOCK No1
PASSAGE 90 FT WIDE SILL 3' 7" BELOW B.D. HUSKISSON DOCK BOTTOM 12' 6" BELOW B.D.
CANADA DOCK BOTTOM 6 FT BELOW B.D.
EXISTING WORK TO BE REMOVED SHOWN DOTTED
1618 FT
SHED 1610 FT LONG
120 FT WIDE
PASSAGE 130 FT WIDE SILL 10 FT BELOW B.D.
CANADA BASIN Hydraulic Power Impounding Station
130 FT WIDE B.D. 23 FT.
LOCK 825 FT LONG SILL 19 FT. BELOW B.D.
895 FT
SHED 720 FT LONG 100 FT WIDE
BROCKLEBANK DOCK BOTTOM 6' 6" BELOW B.D.
AREA TO BE DREDGED TO 10 FT BELOW B.D.
LANGTON DOCK BOTTOM 4 FT BELOW B.D.
1132 FT
SHED 1100 FT LONG 120 FT WIDE
EXTENSION TO NORTHERN OUTFALL AND BANKHALL RELIEF SEWERS
EXTENSION TO MILLERS BRIDGE SEWER
AREA TO BE DREDGED TO 2 FT BELOW SILL LEVEL
RIVER MERSEY
* B.D. = Liverpool Bay Datum
PASSAGE 89 FT WIDE SILL 11 FT BELOW B.D.
ALEXANDRA DOCK POSSIBLE FUTURE DEEPENING TO 10 FT BELOW B.D.
Scale of Feet
Fig. 2.

Port of Liverpool—continued

Canada Lock, from Canada Basin into Canada Dock, though 600ft. long and 100ft. wide, has a depth of only 24ft. of water on the sill at high water of neap tides, and has the disadvantage of being difficult to work in foul weather, as it faces a north-westerly direction and is exposed, at high water, to seas running in across Liverpool Bay. The remaining entrance in use, the easterly of the two from Canada Basin into Langton Dock, is even shallower and has a width of only 65ft.

With increasing numbers of ships drawing 30ft. and over using the port, and with the importance of a quick turn-round being greater than ever before, the provision of a second deep-water entrance, comparable with that at Gladstone, has become imperative.

Site of the Lock

For the site of the new lock, Canada Basin has been chosen. It may be remarked that it is the only remaining example of the large tidal basins which were a distinctive feature of river-entrance design nearly one hundred years ago. It has the advantage of being near the middle of the system, and, in addition, the entrances which will be rendered redundant by the new lock will form part of the site of the new works and thus will be automatically extinguished.

Although the remainder of the system is well suited to shipping requirements, the general lay-out adjacent to Canada Basin is somewhat inadequate in respect of both land area and water space. These shortcomings will be remedied by the filling in of Canada Basin and the realignment of the quays.

A further advantage of the site is that there will be a considerable saving in repairs and replacements to offset against the cost of the new scheme. Canada Lock and the Langton Entrances are in poor condition, partly owing to age and partly to extensive bomb damage sustained during the war. The quays in the vicinity are also in bad condition, for the same reasons; in some places it is known that large underground cavities have formed owing to the internal erosion caused by water which has been percolating through the ground from the docks to the river.

For these reasons, therefore, it has been decided that the scheme shall include the reconstruction of the west quays of Langton, Brocklebank and Canada Docks, in addition to the construction of the new lock and the complementary widening and deepening of the passage between Brocklebank and Canada Docks.

Outline of the Scheme—The Lock

The new lock [Fig. 2] will have a clear length of 825ft. between inner and outer sliding caissons and a width of 130ft., while sill level will be 19ft. below Liverpool Bay Datum. Bay Datum is the chart datum for the port and is 14.54ft. below Ordnance Datum or 10-ft. below Old Dock Sill Datum, which is still used as the datum for engineering construction on the docks, and is, as the name implies, the level of the sill of the Old Dock, the first enclosed dock in the port, opened in 1715.

The extreme tidal range is ordinarily 34ft., from 2ft. below Bay Datum to 32ft. above, though an abnormal high-water level of 34ft. above Bay Datum has been recorded. Impounded level is approximately 28ft. above Bay Datum, and when the water level in the river exceeds this, the system becomes tidal. On these occasions, it is the practice to close the gates at high water to avoid the danger of it being impossible to close them successfully once the ebb run through and out of the system has set in.

It has been decided that the lock caissons shall be designed to operate at a minimum water-level of Bay Datum, and, consequently, the maximum lift of the

Port of Liverpool—continued

lock will, in practice, be about 30ft. Fig. 3 shows the number of hours over any tide, from springs to neaps, during which ships of different draughts will be able to use the lock.

To save time and undue loss of impounded water when working smaller craft through, the lock chamber will be divided by a middle caisson into two compartments, the smaller of which will have a clear length of 275ft. and will be able to accommodate the Board's new diesel-electric grab dredgers.

The lock will be provided with emergency sills and checks at its extreme ends for sealing off by ship caisson, so that the lock chamber can be pumped out for inspection and repairs to the invert, sills, caisson runways, etc., with a minimum of delay. Between emergency sills the length of the lock will be 933ft. Coping level will be at 40ft. above Bay Datum, and the height of the walls measured from sill level will be 59ft.

A new river wall will be built for a length of 500ft. outside the west wall of the lock, converging towards it from the present river wall to the north-west of Canada Basin, thus forming a pierhead about 50ft. wide at the outer end of the lock.

The approach to the lock from the dock will be cleared by the removal of the tongues between Langton and Brocklebank Docks. The invert of the Langton-Brocklebank Passage will be removed and an area dredged to 10ft. below Bay Datum to give a deep manœuvring space; eventually a fairway will be dredged to the same depth through Alexandra and Hornby Docks to the Gladstone-Hornby Lock to communicate with Gladstone Dock.

Canada-Brocklebank Passage

For ships moving to berths south of the new lock, the passage between Brocklebank and Canada Docks, now 79ft. 9ins. wide with

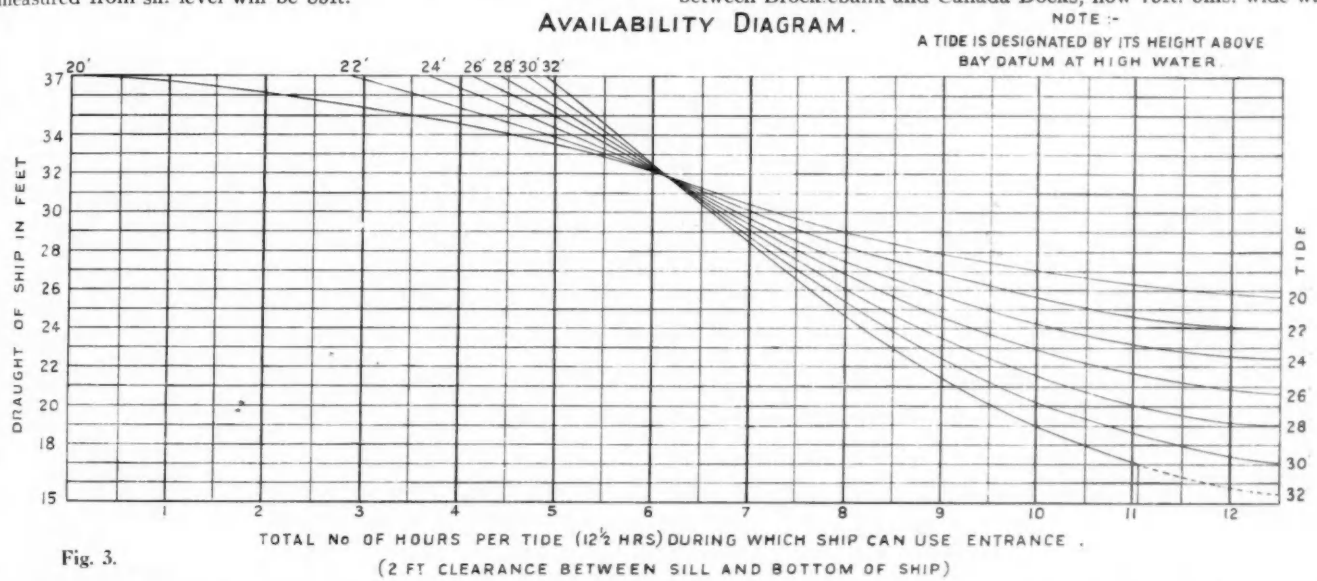

AVAILABILITY DIAGRAM.
NOTE :-
A TIDE IS DESIGNATED BY ITS HEIGHT ABOVE BAY DATUM AT HIGH WATER.
20' 22' 24' 26' 28' 30' 32'
DRAUGHT OF SHIP IN FEET
37 34 32 30 28 26 24 22 20 18 15
TIDE
20 22 24 26 28 30 32
1 2 3 4 5 6 7 8 9 10 11 12
TOTAL No OF HOURS PER TIDE (12½ HRS) DURING WHICH SHIP CAN USE ENTRANCE .
(2 FT CLEARANCE BETWEEN SILL AND BOTTOM OF SHIP)

Fig. 3.

Levelling will be effected by means of culverts incorporated in the side walls, with outlets spaced uniformly along the length of the lock, and controlled by hydraulically-operated sluices duplicated by hand-operated sluices. Flushing culverts will be provided to clear the caisson chambers of silt before it becomes consolidated.

Provision will be made for sealing each caisson chamber by a portable dam, which will be in sections for convenient lifting and stowing.

Each caisson will be interchangeable and, therefore, it will be possible to utilise the middle caisson chamber as a dry dock for minor repair work to any of the caissons and, at the same time, to retain the full length of the lock in use.

The lock will face up-river, mainly to avoid the direction from which the worst seas come. The east wall will be continued up-river from the outer end of the lock in a curve of 1,600ft. radius through an angle of 14°, whence it will be carried on as a straight approach wall for about 1,500ft. to join the present river wall abreast of the southern end of Canada Dock. This new wall will be used as a lay-by and to facilitate the working of vessel's using the entrance.

The small angle of the lock with the general run of the river is desirable on account of the velocity of the tidal stream, which reaches about 3¼ knots on ordinary spring tides and about 5 knots on both the flood and ebb of equinoctial spring tides. The corresponding angle for the Gladstone River Entrance lock is also 14°, where it is found to be very satisfactory, being small enough to avoid the adverse effect of a strong cross-tide on vessels, yet great enough to allow them to clear the river wall comfortably even with a strong wind blowing across the river.

The river bed gradually slopes up from about 65ft. below Bay Datum in mid-river to about 5ft. above at the river wall; therefore, an area will be dredged at the approach to the lock in which vessels will be able to manoeuvre.

the sill at 4ft. 3 ins. below Bay Datum,, will be rebuilt to have a width of 130ft. and a sill level of 10ft. below Bay Datum. This is 4ft. lower than the present dock bottom on either side of the passage, and is a provision for the future deepening of Brocklebank and Canada Docks.

A sliding caisson will be installed at the passage capable of taking a full head of water in either direction; should an accident occur at the entrance lock it would serve to isolate the effects of a run-down to Langton and Brocklebank Docks and maintain the impounded water level in the docks to the south. It will carry a 20ft. roadway, with a single-line railway track, and two 4ft. footways across the passage on a falling deck. When the caisson is drawn back into its chamber, the deck will fall about 4ft. 6ins. and pass under the cross girders supporting the chamber roof.

New Quays and Subsidiary Works

To give ships using the new passage a clear approach, the west quay of Brocklebank Dock will be rebuilt on a line 85ft. back from the west wall of the passage. One result of the widening of Brocklebank Dock will be to improve the approach to Brocklebank Graving Dock to such an extent that, for the first time since its conversion from a wet dock in 1905, it will be available for single ships up to its full length of 800ft.

The new quay will be wider than the present one owing to the filling-in of Canada Basin. Space will be available for a single-storey transit shed, 720ft. long by 100ft. wide, with a double line of railway tracks and a roadway having a clear width of 30ft. at the rear. On the dock side, a quay margin of 18ft. will be allowed for to provide trucking space; there will, however, be no railway track on this side.

The west quay of Langton Dock will be considerably widened by moving the quay line forward into the dock about 75ft. at the south end and 100ft. at the north end, giving space for a double-

Port of Liverpool—continued

storey transit shed 1,100ft. long and 120ft. wide. On the dock side the quay margin will be 33ft. to accommodate a double line of railway tracks and portal cranes. At the rear of the shed, there will be space for double railway tracks and a roadway of 40ft. clear width. The west passage between Langton and Alexandra Docks, which is no longer in use, will be filled in.

The west quay of Canada Dock will be both widened and lengthened. The lengthening will be effected at the north end by the removal of the masonry tongues flanking Canada Lock where it projects into Canada Dock. In this way, about 525ft. will be added for a loss of 450ft. of much less valuable quay on the east tongue of Canada Lock.

The increased width will be achieved by moving the quay line forward about 55ft. at its present north end, but at the south end it will be moved only slightly; additional width will also be gained by virtue of the new river wall being constructed outside the present river wall.

Space will be availabe for a double-storey transit shed 1,610ft. long and 120ft. wide, with a similar arrangement of railway tracks, and the same quay margin and roadway width as on the west side of Langton Dock.

Upon completion of the scheme the total length of long berths will remain practically unchanged at about 3,600ft., while there will be a reduction in the length of less useful short berths from about 935ft. to 325ft.

Three large town sewers, at present discharging into Canada Basin, will be diverted and extended to discharge directly into the river. Two of these run down the tongue between Canada Branch Dock No. 3 and Brocklebank Graving Dock. The larger of these, constructed about 25 years ago, passes under the Canada-Brocklebank Passage in a 9ft. diameter inverted syphon, formed in a tunnel in the underlying rock, and lined with cast-iron segments. Owing to its depth, it will not be necessary to disturb this syphon on deepening the passage, but the other sewer will require a new syphon, the first 100ft. of which will be constructed in a heading in the rock in order to pass safely under two large levelling culverts, which cross the tongue about 50ft. east of the passage. On the west side of the passage the two will join and run in a single large sewer to a low-level outfall in the river wall about 400ft. south of the new lock.

The third sewer runs down the tongue between Brocklebank Branch Dock and the Langton Graving Docks, and will be diverted in a direct line to the river, passing under Langton Dock in a rock tunnel.

When Canada Basin was enlarged in connection with the construction of the Langton Entrances, about the year 1880, the level chosen for the bottom was lower than any that had previously existed at the approach to an entrance on the Liverpool side of the river, and it was rightly concluded that the depth in the basin itself and in the fairway would not be self-maintaining against silting. The bottom of the northern half of the basin was excavated and covered with a three-foot slab of concrete, the top surface of which was 2ft. 6in. below sill level. Three lines of cast-iron sluicing culverts were laid under this floor, with upcast outlets at intervals, each outlet being protected by a heavy greenheart disc anchored by loose links to act as a non-return valve to prevent the ingress of silt when the sluices were not in use, and to spread the issuing sluicing water over the surface of the floor. Sluices were provided in the walls flanking the basin, and to clear the fairway, two timber jetties incorporating sluices in their bases were constructed on the splay from either pierhead, projecting about 200ft. into the river. At a later date, in connection with the deepening of Canada Lock, a third bank of sluices was constructed across the south-east corner of the basin to clear the lock approach.

These timber jetties and the incorporated sluices will be demolished, as also will be the existing sheds and other buildings.

Comprised in the scheme are the ancillary buildings and offices connected with operating and maintaining the new lock. These include residences and offices for the dock master and his principal assistants, gatemen's huts, stores and shops for minor repairs, etc., and a canteen for the dock workers.

An important subsidiary work will be the construction of a new impounding station to relieve the present one situated at the south end of the Gladstone River Entrance, and to provide additional pumping capacity to make good the extra water that will be lost by the use of the new lock. The intakes will be in the river wall about 100ft. south of the new lock, and two delivery culverts will be provided, one into Canada Dock and the other into Brocklebank Dock. The capacity of the station will be somewhat greater than that of the Gladstone station which is equipped with four fifty-four inch electrically-driven centrifugal pumps, each having a capacity of 50,000 gallons per minute.

A new hydraulic power station, to deliver water at a pressure of 850 lbs. per square inch, will be constructed to replace the obsolescent steam station situated on the west side of Canada Lock, and will adjoin the impounding station.

Estimates indicate that the complete scheme will cost about £10,000,000, and will entail at least six years' work.

Preliminary design has been in hand for some time, but as there is still much to be finally settled, it is only possible to give a general indication of the form most of the work will take, without being definite on all points.

Proposed Programme of the Scheme

A tentative programme of work has been drawn up covering the whole scheme. The first stage of the work, covering two years, centres round the reconstruction of the passage between Canada and Brocklebank Docks. This work will be carried out under the cover of cofferdams and in deep trenches, and includes the extension of the two 12ft. 6in. by 13ft. 6in. levelling culverts on the east side of the passage. The other works in this stage will be the construction of the new west wall of Brocklebank Dock so that ships may use the new passage, the diversion and extension of the sewers and the preliminary work on the construction of the lock.

So far, the general features of the scheme have been discussed, and there now follows a more detailed discussion of certain aspects of the work.

Caissons—General Considerations

Sliding caissons will not be an innovation for the port, as Gladstone Graving Dock and the wet basin of Messrs. Cammell Laird & Co., Ltd., the Birkenhead Shipbuilders, are both so equipped. It is, however, the first time that the Mersey Docks and Harbour Board have decided to install one at a lock or an inter-dock passage. The comparative advantages and disadvantages of mitre gates and caissons have been discussed elsewhere; it is the opinion of the Mersey Docks and Harbour Board that caissons are preferable for important river entrances, their chief advantages being greater certainty of a successful closure under adverse conditions, greater robustness, and that they can be safely left unattended in the closed position for an indefinite time.

In pre-war Continental practice for important entrances, it was common to install caissons mounted on roller carriages running on rails. In view of the high silt charge in the water of the Mersey and in the light of experience with submerged rollers on other types of structure in the port, it is thought that plain slides will be the more reliable in operation. As very little information is available about the performance obtained with plain slides working on heavy duty, a small-scale test is being carried out with a model caisson to investigate wear and determine a coefficient of friction which could be used in connection with the design of the hauling machinery. The slideways will be of polished granite and the moving slides fixed to the caisson will be of mild steel.

The design and construction of the caissons will be undertaken by a well-known firm with wide experience in this type of construction, and the preliminary designs are well advanced.

Lock Caissons

The three lock caissons will be rectangular in plan with plumb stems, and designed to withstand a full head in either direction; the leading dimensions will be: length over stems 133ft. 6ins., moulded width 29ft. 6ins., width over sill timbers 31ft. 9ins., depth from coamings to slide 56ft. The width of the caisson runway between sill faces will be 32ft.

It is estimated that the structural weight of the caisson will be about 1,350 tons and that 850 tons of permanent ballast will be required, in addition.

Port of Liverpool—continued

Each caisson will be capable of being hauled, without alteration to the ballast, at any water level from Bay Datum to 34ft. above, which is the highest water level ever recorded in the Mersey. In order to conserve impounded water, it will not be normal practice to operate the lock at tidal levels lower than about 10ft. above Bay Datum.

Owing to the unusually large variation in the depth of water in which the caisson will be required to operate, the buoyancy space will, of necessity, be placed as low as possible. As this would result in too high a centre of gravity for stability in the floating condition, the buoyancy space will be sub-divided horizontally by a watertight deck, the lower chamber being flooded before floating. The floating draught will then be about 30ft.

The caisson structure will comprise five decks: the top deck will consist of two inter-connected lattice girders, with space between for accommodating a falling footway, while the four remaining decks will be plated.

As a precautionary measure, in case the buoyancy space is holed, transverse watertight bulkheads will be provided for the full height of the plated decks, in order to restrict flooding. The bulkheads will be at 24ft. centres and located at each alternate main frame.

The arrangements for floating the caisson into place will include a portable strip to the caisson-chamber decking at the coping end, and short removable lengths of sill timber and fendering on the caisson itself. Detaching these lengths, which will be situated close to the tail end, will reduce the effective width of the caisson, thereby enabling it to be worked round the quoin at the entrance to the chamber prior to its being scuttled and hauled back.

The falling footway will be carried on the upper bearings of a series of rocking links pivoted to the framing of the hull at the lower bearings. Two arms projecting forward of the nose end of the caisson and attached to the footway girders carry striking rollers, which, on coming into contact with vertical striking plates set in the nose-end recess, will bring the forward movement of the footway to a stop. The upper bearings being thus restrained, the continued forward movement of the hull will cause the links to rotate about the lower bearings, from an inclined to a vertical position; this motion will be assisted by counterweights fixed at the lower ends of the links.

The hauling machinery, to be housed below ground level in water-tight pits, will be electrically powered, incorporating Ward-Leonard speed control, and a mechanical two-speed gear change to cater for the large difference in the hauling load between high and

(Photo by Elsam, Mann & Cooper Ltd.

Fig. 4.—Aerial view of the North Docks with Gladstone River Entrance lock and Gladstone-Hornby Lock in the foreground. The photograph was taken in 1947 and work can be seen in progress on the repairs to Gladstone-Hornby Lock, the reconstruction of the shed on the south side of Gladstone Branch Dock No. 1, and the construction of the new shed on the west side of Alexandra Dock.

Port of Liverpool—continued

low water. Two completely independent electrical power units will be installed, either of which will be capable of hauling the caisson. To provide against a failure of the electrical equipment, two hydraulic stand-by engines will be incorporated. The hauling speeds will be approximately 33 and 22ft. per minute with the electric drive, and 10ft. per minute with the hydraulic.

Each caisson will be operated by a pair of endless plate-link sprocket-driven chains, working in recesses down either side of the caisson chamber. A transverse hauling bar, spanning from chain to chain, will be connected at its centre point to the caisson by a triangular yoke.

Passage Caisson

The passage caisson will be of the same length and breadth as the lock caissons, but will have a sill higher by 9ft. and will not be required to operate through so great a range of water levels. It will, therefore, be more conventional in design, having four decks, between the middle two of which the buoyancy space will be situated, and, as in the case of the lock caissons, this space will be sub-divided by transverse watertight bulkheads. The caisson will be rectangular in plan with plumb stems and the same provisions for floating into place as the lock caissons have. The principal dimensions will be: length between centres of stems 132ft., width 29ft. 6ins. moulded, 31ft. 9ins. over sill timbers, and depth 46ft. from coamings to slide; the width of the runway between sill faces will be 32ft. It is estimated that the structural weight of the caisson, including the falling deck, will be about 1,200 tons and that 500 tons of permanent ballast will be required, giving a floating draught of about 28ft. 6ins.

The machinery and hauling arrangements will duplicate those of the lock caissons.

The distinctive feature of this caisson is, of course, the falling deck carrying the roadway and rail track. It works on the same principal as the falling footways of the lock caissons, and the estimated weight is about 225 tons, including the counterweights. The lower part of the striking plate will, in this case, be curved upwards in such a manner as to reduce shock on the initial impact.

GENERAL CIVIL ENGINEERING WORK

The Nature of the Ground

The river wall, behind which the docks were constructed, was built along the approximate low-water line of spring tides, the docks occupying the old foreshore. Bedrock over the whole site is a red sandstone of one of the Triassic formations which underlie large areas of South Lancashire and Cheshire. The rock is thickly bedded and of considerable crushing strength, though from the surface down for depths, usually varying between 2ft. and 5ft., it tends to be rather friable, laminated and liable to disentegration on exposure to air. When excavating for foundations it will be important that this weak zone of rock, known locally as roach, should be removed and a bed secured on the hard rock below, which is expected to form an excellent foundation. As it is porous and is known to contain occasional water-bearing fissures, it is preferable to take the possibility of hydrostatic uplift into account in design; springs have been encountered elsewhere in similar rock, though these have usually been dealt with comparatively easily.

The surface of the rock is highly irregular, and several deep drift-filled channels are known to occur in the vicinity. Fortunately there are many old borings covering the area, and much information was obtained during the construction and alteration of the original docks, thus greatly reducing the site investigation work necessary for the present scheme.

Overlying the solid rock is glacial drift consisting mainly of a brownish boulder clay, with interstratified sand and gravel over much of the area. These sand and gravel zones, being water-bearing, have been the source of " blows " in cofferdams in the past. In addition, there are erratic deposits of peat, silt, fine sand and sand and gravel. Above the glacial drift are recent deposits of estuarine mud, etc., and made ground.

Over much of the site of the lock itself the rock level is at, or only a few feet below, the proposed invert level, and, therefore, very little rock excavation will be required. It is expected that it will be advantageous to shatter the rock first by blasting.

Constructional Problems and Methods

Many different schemes for the construction of the lock have been investigated, and consent has been obtained for the building of a temporary earth-and-rubble embankment round the entrance to Canada Basin, with a cut-off of steel sheet-piling, and faced with dumped limestone. This would enable the whole of the basin to be dried out for the construction of the greater part of the lock. Though the large working area thus gained would be of advantage, there are certain serious drawbacks, such as the time absorbed in the construction of the embankment, difficulty of removal and the uncertain amount of maintenance necessary to make good erosion in a fast-running tideway. It seems most likely, therefore, that the scheme which will be finally adopted is that involving the construction of the lock walls in box cofferdams in Canada Basin, the work proceeding riverwards by stages from the inner end, thus taking maximum advantage of the shelter available. The east wall of the lock would proceed in advance of the west, and the filling-in of the basin will be undertaken concurrently. The dams in the more exposed positions required for the construction of the walls to the west of the lock could be steadied by strutting back to the east wall, and then a closing dam would be constructed between these finished walls.

The construction of the inner end of the lock will be undertaken in trench work on the east side, box dams for the west return wall and, finally, a closing dam to seal off the body of lock to allow work on the dumpling and invert.

The Canada-Brocklebank Passage will be reconstructed under cover of two closing dams, preceded by two wall-face dams, a large one at the south-east corner of the present passage and a small one at the north-east corner. The west wall can, however, be constructed in trenches.

A large number of wall-face dams will be required for the river approach wall, the west walls of Canada and Langton Docks, whilst the west wall of Brocklebank Dock can be built in deep trenches.

The filling of Canada Basin will absorb a large quantity of spoil from the site, and it is expected that imported material will be required in addition.

Dams

The cofferdams will most probably be all of the single-skin internally-braced type, utilising cranked-section steel sheet-piles, braced by timber walings and steel struts. These cofferdams will fall into the three categories which have been referred to as " box " dams, " wall-face " dams and " closing " dams.

In the box and wall-face dams the work is carried out within the actual confines of the dam: whereas a closing dam seals an opening and the area kept dry lies mainly beyond the dam itself. The distinction between box and wall-face dams is that, in the case of the box type, the dam is entirely, or almost entirely, surrounded by water and, generally, little or no support from adjacent masonry can be relied upon to counteract the effect of differences in head on opposite faces of the dam: a wall-faced dam is constructed against a masonry wall which also forms one of the major sides of the enclosed space and affords a rigid support for the dam. A closing dam is usually structually akin to a wall-face dam in that it spans between solid abutments.

Clearly, a box dam is less stable in a seaway than a wall-face dam and, unless it can be steadied by long shores to adjacent masonry, relies on its stiffness as a cantilever projecting up from the sea bottom to resist the tendency to overturn and to be laterally displaced by the seas. Clay stabilising banks can be tipped on either side of the dam for part of its height to increase this resistance.

Construction of the dams in the docks will entail considerable underwater work by divers, including fixing the struts, making various connections and cutting holes in the masonry to house the ends of shores and walings. Some of these dams will be of considerable size and depth, probably with as many as twelve tiers of framing. The river dams will, it is hoped, require very little diver's work, the construction at lower levels being done at low water.

In many of the dams the internal shoring will run through the space to be occupied by the new construction. In most of these cases relieving of the shores will be preferred to concreting them in the finished work. Relieving is the transference of the load

Port of Liverpool—continued

through a temporary or substitute shore on to the face of the new work, thus permitting the removal of the original shore.

Excavation in Trenches

A considerable amount of excavation will be carried out in deep trenches. Owing to the difficulty in obtaining supplies of suitable timber, it is probable that considerable use will be made of steel sheeting for lining the sides; steel may also be used for the bracing.

Experience is being gained with the use of mechanical excavating appliances, such as the power shovel and skimmer, in the bottom of trenches. Working room is obtained by using cranked-section sheet-piles driven to the full depth prior to the commencement of the excavation, thus providing sufficient lateral strength to allow a considerable vertical interval between the tiers of framing. Where this method is not expedient, steel trench sheeting in short lengths will be adopted and dropped with the excavation as it is sunk.

Water will probably be dealt with by means of landers and sumps in the trenches, as ground-water lowering by well-points, or similar methods, will not be practicable owing to the nature of the soil.

Concrete Work

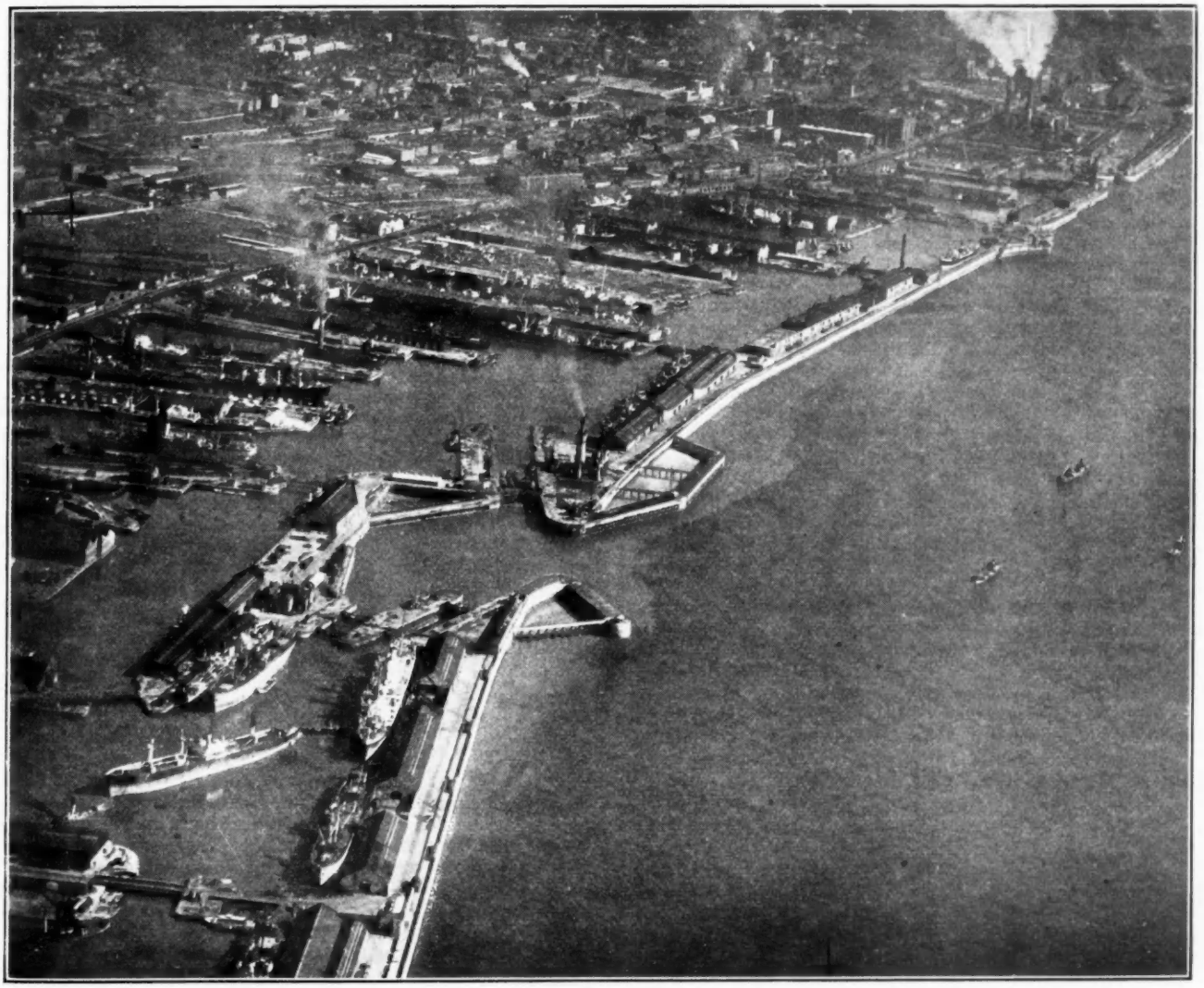
The lock and quay walls will most probably be of full gravity section, executed in mass concrete, with plums where these are available from the demolition of old masonry. Other types of construction have been investigated, but the gravity wall seems the most suitable, having regard to robustness, ease of repair and the nature of the site. All-in aggregate will be largely used, and the cement will be ordinary or rapid-hardening Portland according to the circumstances. It has not yet been decided whether to adopt central mixing.

As an exception, however, the side walls of the passage caisson chamber will be of a heavy reinforced-concrete section, utilising the chamber roof as a support.

The concrete will only be faced where more than ordinary wear is to be expected, such as copings, quoins, caisson slides, sill faces and sluice-paddle bearing surfaces. Granite blocks derived from the existing masonry will be dressed on the site and used for this purpose.

Sewers

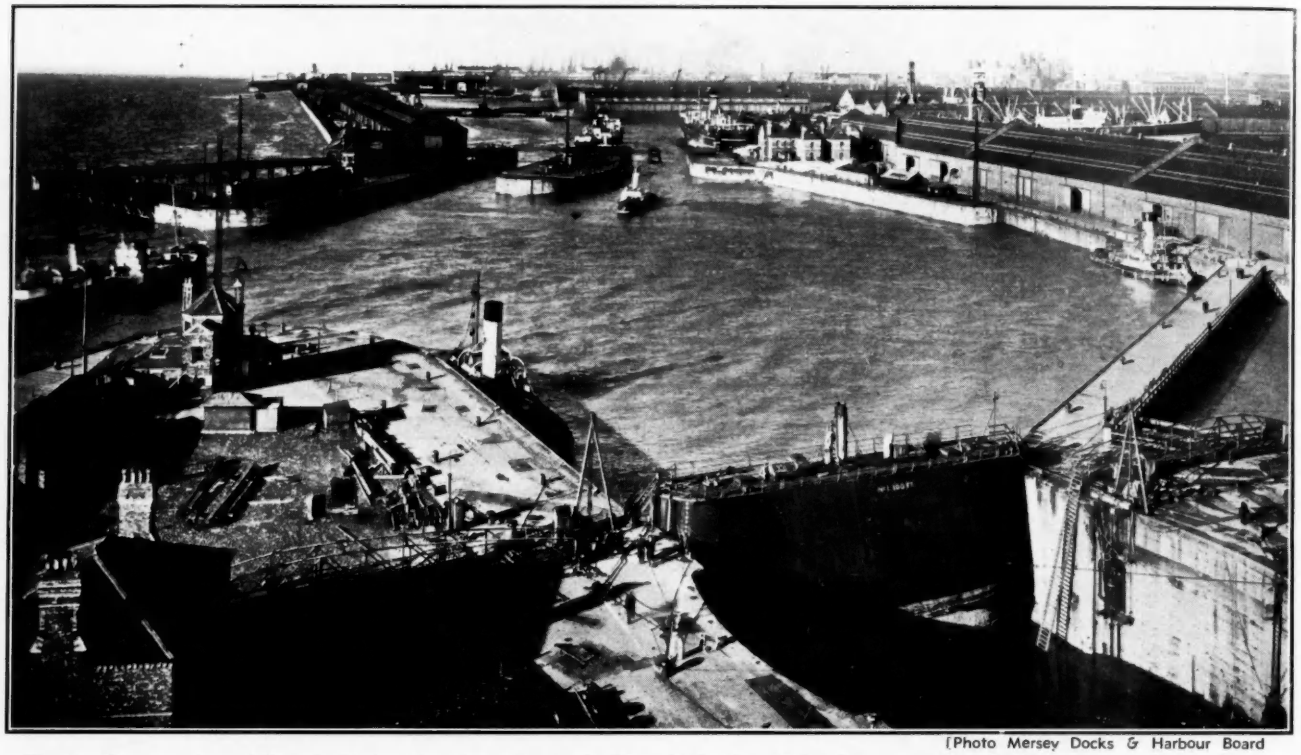
The Northern Outfall and Bankhall Relief Sewers will be extended in reinforced-concrete box culverts, with the exception of the 100ft. of circular sewer in rock tunnel where the Bankhall Relief Sewer passes under the Brocklebank-Canada Levelling Culverts. The sewers crossing Canada Basin will be constructed in box dams and founded on 15in. octagonal precast-concrete bearing piles, driven to rock. The remainder of the sewer will be constructed in cut and cover.



[Photo by Elsam, Mann & Cooper Ltd.

Fig. 5.—Aerial view showing Canada Basin in the foreground and the docks extending southwards to the Sandon River Entrances in the middle distance.

Port of Liverpool—continued



[Photo Mersey Docks & Harbour Board

Fig. 6.—Close-up view of Canada Basin taken from the south side. At the time of the photograph, Canada Lock was out of commission for repairs, and the ship caisson sealing the outer end can be seen in the bottom right-hand corner. The alignment chosen for the new lock is from A to B.

The new syphon under the passage will be fully lined with engineering brick; in all other sections the invert and side walls only will be lined.

The Miller's Bridge Sewer will be diverted under Langton Dock by means of a syphon constructed in a rock tunnel about 800ft. long. It will be possible to work from three shafts; the middle shaft will be temporary only and will be situated in the tongue separating Brocklebank Dock from the south of Langton Dock, thus reducing the maximum length between working shafts to 500ft.

It is hoped to carry out this work in free air but if compressed air is necessary a lining of cast-iron segments will be incorporated.

The sewer will be circular in section, the internal diameter being 6ft. It will be lined with engineering brick backed with concrete, giving an overall diameter of 9ft. 3ins.

The sewers will be provided with sluice gates and branch culverts from the docks for the regular flushing of the syphons. Should it be necessary to isolate the syphons for inspection, the flow can be diverted into the docks through these flushing culverts.

Sheds

Although they form a very important part of the complete scheme, any attempt to give details of the proposed sheds and cargo-handling appliances would be premature at the present time. It is safe to say, however, that the foundations will almost certainly incorporate a large number of precast-concrete bearing piles.

Dredging

The principal dredging plant will be bucket-ladder dredgers, working in conjunction with rock breakers if necessary. Grab dredgers will also be required to deal with loose debris.

It is estimated that the river approach to the lock will require the removal of a net quantity of 1,100,000 cubic yards of soft material and 160,000 cubic yards of rock. The bucket dredgers can usually deal with the top five to ten feet of rock without previous preparation, but at greater depths the hardness generally warrants the dredger being preceded by a floating rock breaker with a view to expediting the work and saving undue wear and damage to the dredger. A rock breaker with a 10-ton needle working on similar material in the port, shattered rock to a depth of 3ft. at the rate of nearly 10 cubic yards per hour.

Dredging in the docks will include the excavation of clay from the dock bottoms, and the removal of old masonry and fill from demolished quays; the old masonry will have been previously collapsed by borehole charges.

Conclusion

Following their usual practice, the Mersey Docks and Harbour Board will carry out the design and construction of the heavy civil engineering work departmentally, employing their own engineering staff, plant and labour. An exception is made, however, of certain items, such as tunnelling, sliding caissons and the fabrication and erection of steelwork, which will be entrusted to outside specialists in these types of construction.

The authors wish to express their indebtedness to L. Leighton, Esq., M.I.C.E., M.I.Mech.E., Engineer-in-Chief to the Mersey Docks and Harbour Board, for his advice and the opportunity to write this article.

Further Transfers of United Kingdom Docks.

It was recently announced that Garston and Fleetwood Docks will be transferred to the Docks and Inland Waterways Executive from the Railway Executive, as from December 1st, 1949. The docks at Barrow, Silloth, Lydney, Grangemouth, Ayr, Troon, Methil, Burntisland, Alloa, Alloa (South), Bo'ness, Charlestown, Pettyour and Tayport will be similarly transferred next month.

New Chief Engineer to Tyne Improvement Commission.

At a meeting of the Tyne Improvement Commissioners at Newcastle held early last month, Mr. R. B. Porter, B.Sc. (Eng.), M.I.C.E., was appointed Chief Engineer in succession to the late Mr. A. L. Harvey. Mr. Porter, who is 48 years of age, has been with the Commissioners since 1927, and has successively held the appointments of Assistant Resident Engineer and Resident Engineer at the Commissioners' Docks; the position of Senior Assistant Engineer to the Chief Engineer and subsequently Chief Assistant Engineer.

Correspondence

To the Editor of *The Dock and Harbour Authority.*

Dear Sir,

Canals and Inland Waterways

Since the comprehensive survey by Mr. Ives of the Docks and Inland Waterways Executive appeared in your May issue, space has been given to a wealth of comment and criticism, mostly constructive and authoritative. Throughout, there runs a deal of sympathy for the Executive in the task which lies ahead, and about decisions which must be made. Indeed, some of the assets inherited are in such a sorry state, both in fact and potentially, that the task of getting them into good health would seem well nigh impossible. One hundred years have passed, as Mr. Gardner remarks, since canal owners first failed to display that initiative, and that capacity for adjustment amid changing conditions, which alone ensure complete survival; since then, bitter opposition by other transport interests, often themselves with a strangle-hold on key navigations, hastened the contraction of the industry.

If the Executive's first year's canal accounts* (not forgetting the £19 for publicity) appear unpromising, it must be recognised that the next may be even more depressing, for the Executive has inherited further doubtful assets, in the form of canals, previously railway-owned. If the costs are known of those canals and carrying organisations, which, thanks to vigorous direction, were healthy before nationalisation, the same cannot be said of those whose accounts were obscured by being incorporated with railway receipts and costs. But it is easy to estimate that the Kennet and Avon Canal, for example, is not likely to be immediately profitable. The annual wage bill cannot be less than £5,000, and the pumping station at Crofton, although a credit to the engineering staff responsible for its excellent state of repair, and although of very great historical interest, consumes several hundred tons of rail-borne coal yearly. But rarely a boat stirs the weeds or disturbs the mud, and the receipts from navigation between Bath and Reading cannot far exceed £10 per annum—and this a 14 foot canal!

Thus, any sympathy for the Executive which has been shown is surely well merited, although it is not improper for suggestions to be made, or to hope for some response.

There is general unanimity that, as a long term policy, the enlargement of certain canals, at present only accommodating narrow boats, is essential, integrating these with existing waterways already of greater dimensions and consequently operating economically. The current price of labour cannot be met by any other means. Professor Gilbert Walker recently remarked that the system of British railway operation still reflects too much the tradition of "cheap pairs of hands" from a by-gone era. If drastic re-organisation is demanded there, a study of narrow boat working on the purely economic plane forces a similar conclusion with even greater emphasis.

But such a long term plan does not fit the present national need for retrenchment and economy in capital expenditure, so that, even if it were formulated, its immediate implementation could not be advocated, until the contrary conditions exist, and national policy demands major new capital works. Nevertheless, it is reasonable to ask for precise information about those canals planned for modernisation, and those for extinction and sacrifice.

What short term plan can be suggested for the main narrow canals, which will not conflict with their ultimate modernisation? Wholesale abandonment is no solution and, in any case, much of the maintenance cost would continue, even without navigation. This is not to say that some pruning of the "tree" would not improve its health. However, if national policy demands minimum capital expenditure, equally it demands maximum use of existing assets, both physical and human. Furthermore, since these canals proved of great value during the last war, their continued existence in working order is surely justified on strategic grounds, even if, at the moment, the railways are no longer grossly over-stressed, and if any route is to be kept in service for such specialised traffic (e.g. oil, tar, carbon disulphide) as Mr. Lyon mentions, any saving by eliminating other traffic will only amount to the marginal cost, which from the canal owner's standpoint is very small. Finally, the economic plane is not the only one on which any short term plan must be studied; people are not merely numbers on a sheet of statistics (except perhaps in a totalitarian state). If the boatmen are forced off the canals, or allowed to drift, this amounts to national loss of that skill and effort, which will be sorely needed when modernisation has been completed.

There are grave signs that our people are losing the capacity for hard work; the boatmen have not done so—yet! It is still usual, for example, for a boat crew of husband and wife to work from Middlewich to Birmingham without stopping, a journey requiring some 32 hours—say, from 5 a.m. one morning until the afternoon of the day following. Can we afford to allow any form of livelihood and craft where such intensity of work is habitual to pass out of existence?

Relief will follow from recognition of the two major frustrations to efficient narrow boat operation by Executive and carrier alike. The first is the present condition of reduced loading and impeded travel—in the words of the boatman that "the bottom is too near the top". Dredging, especially under bridges conducted exclusively on routes in constant commercial use, would go so far towards overcoming present handicaps, that allocation of plant with utter disregard to previous ownership, and even the allocation of long distance boats and crews to this task temporarily would be justifiable. Certainly lengthsmen, and even toll staff, could be found whose daily productive work at present could be foregone. If the very existence of their employment were at stake, would they not respond to such an appeal? If reduced loading, and constant delays due to becoming "fast," or the engine being stopped by rubbish in the propeller, were all eliminated, earnings, at present dangerously low, would rise enough, and morale even more, to stop the drift from the industry. Profit to carriers and the Executive, and reduced boat repairs, would likewise follow. If by intentional complete neglect of such canals as now carry a boat a week, and redeployment of plant and man-power to suit, such routes become virtually impassable, the sacrifice would be worth while.

Secondly, conditions could be created more favourable to elimination of idle time and empty boat working, if new traffic suited to the canals were attracted to dilute the present concentration of traffic in the few categories exising at present, at any rate to and from the Midlands.

This is no simple task, but the Executive has experienced staff, both from the carrying subsidiaries and the independent carriers acquired. That the present situation is none too healthy is typified by the almost complete lack of traffic out of Birmingham, despite the increased flow of exports. Coupled with this, is the fact that some of the traffic at present carried is not ideally suited for canal transportation, or, at least, such is the impression gained from the number of transhipments between ship and consignee—all with much muscular effort and little of the palletisation and mechanisation which modern conditions demand. The obvious traffic for canals is that to be shifted to and from points alongside; that so much of the traffic actually carried is not of this nature, and is not such as would give the canals any inherent advantage in competition, reflects great credit upon those carriers whose initiative first obtained the traffic. But it will be a happier sign when new freights for the movement of which the canals are naturally suited are seen.

Pleasure traffic may make some minor contribution, but not if it is allowed to obstruct commercial craft on busy routes, or distract canal staff from vital work on behalf of commercial traffic. It is significant that of the figures quoted for pleasure boats, which are, of course, those fixed before nationalisation, the highest are those on routes previously owned by independent undertakings, noted for their enterprise in commercial traffic. However, those canals, such as the Trent and Mersey east of Stoke-on-Trent, and the Oxford south of Napton, which must be maintained as alternative commercial routes, in the event of stoppages on the main arteries, might well be developed for pleasure craft. Remembering that a pleasure boat uses as much water as a loaded boat, the tolls charged, although seemingly penal to the pleasure seeker, represent in truth a privilege, possibly justifiable if, thereby, weed

*[Ed.—These accounts cover the profit and loss of The Canal and Inland Waterways section only of The D. & I.W.E., thus "Canal Accounts" is more appropriate.]

Correspondence—continued

growth is checked and the mud and rubbish suffer welcome disturbance.

Publication by the Executive of long-term proposals, with details of those waterways to be modernised, and, where unavoidable, those to be abandoned is awaited. It is hoped that such a statement of policy, accompanied by drastic first-aid remedies, will revive morale, especially amongst boat crews. If the consequent budget must entail a deficit, the public are accustomed to such subsidies, where it is in their long term interest.

Mr. Gardner very aptly calls for a policy, for the generalship of a Montgomery. Let us not forget that the reputation of the Field Marshal largely rests on his insistence upon sufficient preparation, on his rebuttal of demands for undue haste with the "Second Front," with such results as we will not easily forget.

It is not easy for the observor to distinguish between the silence while a plan is being laid in secrecy, and the sealed lips of those who would disguise their incapacity to make one. But, like the brilliant General, the Executive must know, if no D. Day dawns at last, how awful would be the retribution.

Yours faithfully,

17, Blomfield Road, G. L. H. BIRD.
London, W.9.
22nd November, 1949.

The Payment of Dock Workers

Urgent Need for Incentives

By GEO. B. LISSENDEN, M.Inst.T.

The National Arbitration Tribunal, in a recent award, stressed the view which it had expressed in a previous award, that the electrical contracting industry in England and Wales "is one in which a production incentive scheme should operate." More recently still, Lord McGowan, Chairman of Imperial Chemical Industries Limited, addressing the first of a winter series of "free enterprise" meetings organised by the National Union of Manufacturers, said: "What we need is not a wage structure guaranteeing a certain standard of living, but a wage policy of incentives and sanctions which will encourage the industrious and penalise the lazy."

During the last two or three years a similar view has been put forward in respect to other specified industries, but, so far as the author of this article knows, no one has yet made a definite, concrete recommendation for dock workers. He therefore wonders why, having regard to the fact that an incentive for dockers would help to solve some of the pressing economic problems which are confronting the United Kingdom.

Piece Rates Not Universal

One knows, of course, that piece rates are paid for the discharge of certain cargoes in a few of the British ports, but such incentives are not universal—as, it is submitted, they should be. The writer has been convinced of this necessity for the greater part of his working life, but he had it forcibly impressed upon him during the last war, when some of the London dockers were transferred to the Merseyside to help load and unload the ships using the port of Liverpool. The London men simply hated the local day rates and—especially when they were handling anything like scrap steel, timber and bagged stuff, which was "right up their street"—begged the writer to give them "something to work for, some special inducement." Of course, he was helpless. But it was obvious that the output would have been far greater if the men's request had been granted.

It was useless to speak of what the men who were in the firing line were doing, or preach altruism. Those special pleadings may have had some force many years ago, but they have none to-day.

For and Against Incentives

All the arguments for and against a piece-work system are very well known. It is said that when men get on in years they cannot stand the pace; that when working at high pressure, in order to increase the size of their pay-packet, the men are less inclined to take care of the goods they are handling, and so forth. But it is the final analysis of any job that counts in the long run. And it is not beyond the wit of a stevedore so to organise his labour that the gangs for the various jobs are arranged in age-groups, so that the vigorous young-bloods are not dependant upon the "Fillits" and "Wheelits."

As everyone knows who had to do with the loading and discharging of ships during the period of the last war, there were many elderly men employed in dockland in those trying days, and those old men gave a very good account of themselves. They were, naturally, slower than the rest—especially as the day wore on—but the right spirit was there, and that was worth a good deal.

Obviously the older dockers were not put to work with men half their age; it was a case of allocating them to those jobs which they were best fitted to do—on the quay, or in the shed; certainly not down in the hold of the vessel.

Wastage of Labour

It has often been said that there is a certain amount of wastage of labour in dockland—that, in some instances, there are too many men to a gang; that trimmers idle their time, sometimes for hours at a stretch, in the wings of the ship while the crane and grab, or lift and shute, or whatever the cargo-handling appliances may be, do the work. These charges have to be admitted. Some gangs could be reduced, and often enough trimmers or, at any rate, full gangs of them are not required until—in the case of bulk oil seeds or grain, for example—a large proportion of the ship's cargo has been discharged; or, in the case of a full cargo of coal, until most of it has been shot into the vessel.

But the men are hardly likely to agree to any reduction in the strength of a gang unless they are convinced that they will profit by the change. Dock workers are, as a body, suspicious and clannish, and know the history of dockland too well to approve of any scheme at first sight, no matter how honestly and sincerely it may be presented to them.

The Men to Regulate their Earnings

The first step should be to give the dock workers an opportunity to double—yes, and even treble—their weekly earnings. It is a fairly simple matter to propound a scheme whereby both employer and employee profited. But great care would have to be taken to ensure that it was as near fool-proof as human ingenuity could make it, and that no attempt was made to put a brake on the men once it was seen that their earnings were soaring high.

This is said because the writer has known instances of where men have been led to believe they were on a good thing, only to find that they were on a bad one. The dockers will not have anything of that sort. But get their confidence, let them see all the relevant facts and figures, and convince them that they are going to get a square deal—that it is, in other words, a question of share and share alike—and they will be ready to give the scheme a trial, to say the least of it.

Human Nature Does Not Change

From one end of the social scale to the other, we are, to be frank, all similar in our outlook, and like to be amply rewarded for what we do, whether it is the investment of capital or mental or manual labour that constitutes our means of livelihood. Disguise it how we will, there is no gainsaying the fact that a docker is no different from any other class of man: each thinks in terms of what any proposal means to him, his wife and family, and it is fooiish to shrug and say it shouldn't—mustn't—be so.

Some of the Continental ports—Rotterdam and Hamburg are two outstanding examples—make us look amateurish in the matter of cargo-handling, and it is quite time we abandoned *all* our restrictive practices, gave our labour its head, and feared no one in the markets of the world. In short, put an economic and social value on conscious, well-directed effort, and so ensure that our output increases automatically. There is simply no other way. Mechanisation is of little use unless the man behind the machine has a personal (money) interest in what he is doing.

The Corrosion of Metals

Excerpts, bearing upon Cathodic Protection Methods, from a Lecture given before the Royal Society of Arts

By W. H. J. VERNON, O.B.E., D.Sc., Ph.D., F.R.I.C.
(Chemical Research Laboratory, Department of Scientific and Industrial Research).

General Principles

Man's long succession of triumphs in reducing one metal after another from the earthly minerals at and beneath his feet has brought in its train the problem that we know as corrosion. By this is understood the wastage of metals by chemical or electrochemical agencies in the diverse environments in which they have come to be used. In modern times the problem has assumed especial significance, since it is upon the more corrodible metals, notably iron and steel, that the greatest demands of industry and commerce have been made. To the actual loss of metal must be added, completing an economically vicious circle, the still greater amounts of ore, fuel and fluxes used up in its replacement.

Nature of Corrosion

The reduction of a metal from its state of combination in nature being achieved by the expenditure of energy—sometimes in substantial amounts—it follows that only for the " noble " metals is the metallic state natural and stable. For other metals there must be a constant effort to revert to the stable condition of the mineral, with the liberation of energy corresponding to that expended in its reduction. In so far as this effort succeeds, corrosion is the immediate result. If the transition to the stable condition is allowed to go to completion, a definite mineral form is reproduced.

Electrochemical Characteristics

The tendency of a metal to corrode may be expressed numerically by the amount of energy liberated in the change from the metallic to the oxidised state; or, in electrochemical terms, by the standard electrode potential of the metal. In the familiar " electrochemical series " (Table I) the metals are arranged in order of their electrode potentials, the " noble metals " (platinum, gold, silver) appearing at the " electropositive " end, the more reactive metals (e.g., aluminium, magnesium) all the electronegative end of the series. Incidentally it may be observed that—for reasons that will be appreciated—the order is roughly that in which the metals became known to man. Instructive though the table is, it will be at once apparent that it cannot tell us either the rate or the mode of corrosion in a given environment (otherwise the story of corrosion would be much simpler than it is); i.e., other factors must be superimposed upon the initial tendency to corrode as represented by the values shown. Taking aluminium as an outstanding example, its very reactiveness is responsible, under many conditions, for the formation of a tenacious film of oxide (alumina) which effectively suppresses further attack on the metal beneath; this property which may be encouraged and exploited, depends upon the intimacy of the contact between the oxide envelope and the metal substrate. We can show by an experiment that if this association be impaired (by amalgamation of the surface) the growth of the oxide proceeds in a spectacular manner, consistent in fact with the position of aluminium in the electrochemical series.

TABLE I. The " Electrochemical Series "

Metal	Ion Considered	Normal Electrode Potential* (Volts)
("Noble" End)		
Gold	$Au^{\cdot\cdot\cdot}$ ...	+1.42
Platinum	$Pt^{\cdot\cdot}$ ...	+1.2
Silver	$Ag^{\cdot}$ ...	+0.80
Mercury	$(Hg_2)^{\cdot\cdot}$ ...	+0.80
Copper	$Cu^{\cdot\cdot}$ ...	+0.345
[Hydrogen ...	$H^{\cdot}$ ...	0.000]
Lead	$Pb^{\cdot\cdot}$ ...	—0.125
Tin	Sn ...	—0.135
Nickel	$Ni^{\cdot\cdot}$ ...	—0.25
Cadmium	$Cd^{\cdot\cdot}$ ...	—0.40
Iron	$Fe^{\cdot\cdot}$ ...	—0.44
Chromium ...	$Cr^{\cdot\cdot}$ ...	—0.71
Zinc	$Zn^{\cdot\cdot}$ ...	—0.76
Aluminium ...	$Al^{\cdot\cdot\cdot}$ ...	—1.67
Magnesium ...	$Mg^{\cdot\cdot}$ ...	—2.34
Sodium	$Na^{\cdot}$ ...	—2.71
Potassium... ...	$K^{\cdot}$ ...	—2·92
Lithium	$Li^{\cdot}$ ...	—3.02
("Base" End)		

* Potential in salt solution of normal ionic activity relative to the Normal Hydrogen Electrode as arbitrary zero, at 25°C.

Immersed Corrosion

The liberation of energy which results when a metal corrodes is accompanied by a redistribution of electrons which, if the environment is favourable, may produce well-recognisable electric currents. A consideration of the simple voltaic cell (Figure 1) is helpful in visualising the principal factors. The essential features to observe are (i) the electrolyte, (ii) the more electronegative anode and the more electropositive cathode, (iii) the passage of electrons through the metallic part of the circuit (from anode to cathode), (iv) the passage of ions through the electrolyte, (v) the corrosion of the anode, where positively charged metal ions enter the solution (leaving the metal negatively charged with excess of electrons), (vi) the protective effect at the cathode, where hydrogen ions are discharged (electrons being given up from the metal). All these features find their counterpart in ordinary immersed corrosion, even though separate anodes and cathodes

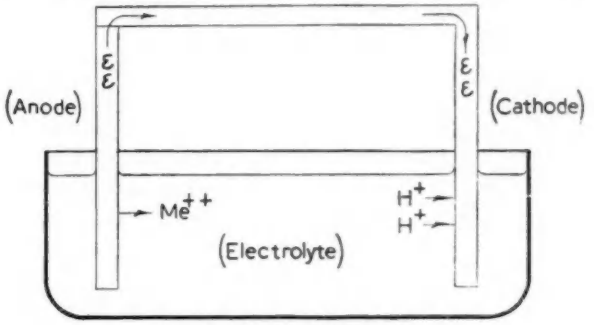


Fig. 1. Simple Voltaic Cell.

cannot always be distinguished visually. We have then to regard —there is, indeed, a good deal of evidence for so regarding— the corrosion process to be made up of anodic and cathodic components which can be influenced respectively by appropriate means.

The simple voltaic cell (in which the electrolyte is a dilute acid solution) ideally represents the " Hydrogen Evolution Type " of corrosion, in which corrosion is a function of the amount of hydrogen evolved. Here, the cathodic reaction may be represented as follows:

$$2\Sigma + 2H^{+} \longrightarrow 2H \longrightarrow H_2 \qquad \text{(i)}$$

Hydrogen evolution corrosion is normally associated with the more acid electrolytes (e.g., acid industrial waters). In neutral salt solutions, however, the accumulation of electrons in the cathode is prevented (except for very reactive metals) only by the intervention of oxygen, which becomes reduced according to the equation:

$$2\Sigma + O + H_2C \longrightarrow 2\,(OH)^{-} \qquad \text{(ii)}$$

This constitutes the " Oxygen Absorption Type " of corrosion. In the more general case in which alkali salts are present, the formation of Hydroxyl ions at the cathode must correspond with the development of free alkali. (In the absence of movement this tends to accumulate near the cathode, or it may spread in a manner determined by geometrical and other factors). The corresponding anodic product is a soluble salt of the metal. Taking as an example iron immersed in a solution of sodium chloride, the anodic product is a soluble iron chloride the cathodic product sodium hydroxide; the interaction of these two substances

Corrosion of Metals—continued

(in the presence of oxygen) somewhere between the two electrodes produces the mixture of iron hydroxides that we know as " rust."

Promoting and Controlling Factors. The factors by which the course of corrosion may be influenced are many and varied. We may, however, distinguish between factors associated with the metal and those associated with the environment. The former

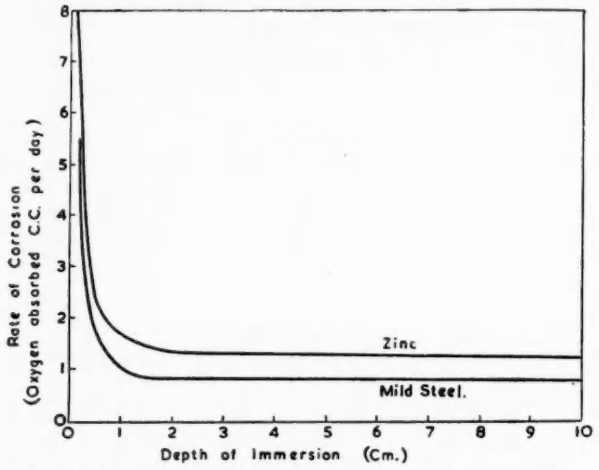


Fig. 2 Influence of depth of immersion on rate of corrosion (Bengouth and Wormwell).

include, e.g., electrode potential, surface condition, inclusions, internal stresses. Because of the not unnatural tendency to focus attention upon the metal, environmental factors are apt to be overlooked. Yet, corrosion being the reaction between metal and environment, they are clearly of equal if not (because of their greater diversity and variability) of greater importance. Again, we may differentiate factors responsible for initiating the attack, i.e., " promoting factors," and those responsible for controlling the subsequent rate, i.e., " controlling factors." It is upon this distinction that I should like to place special emphasis.

If one calculates the maximum amount of corrosion that is theoretically possible the actual amount of corrosion almost invariably falls short of this. Very commonly, in these cases, a " controlling factor " can be recognised which, although apparently subsidiary, is responsible for controlling the rate of attack under a given set of conditions; it does so for the reason that it has the greatest influence in restricting the attack on the metal. Common controlling factors in immersed corrosion are (a) for hydrogen evolution type, factors associated with " hydrogen overpotential "—a complex phenomenon whereby the transition of hydrogen ions to the molecular condition (equation (i) above) is to a greater or lessor extent suppressed; (b) for the oxygen absorption type, the rate at which dissolved oxygen can reach the metal surface (actually the cathodes of the corrosion system). The extreme sensitivity of the cathodes to oxygen supply is reflected in the influence of depth of immersion when the atmospheric pressure at the surface is normal. This is shown by the results of carefully controlled laboratory experiments (see Fig. 2). Under much more complex conditions, the relative freedom from corrosion of the liner " Normandie " after many months submersion may be quoted, in marked contrast with the heavy attack which, in the absence of preventive measures, characterises conditions at the surface. Controlling factors associated with the anodes are more commonly met with in the oxygen absorption than in the hydrogen evolution type of immersed corrosion, and still more commonly in atmospheric corrosion. The principle of the controlling factor is extremely important.

Atmospheric Corrosion

A link between immersed corrosion and atmospheric oxidation was provided years ago by the work of Friend (described in the " Journal of the Chemical Society " in 1921), who increased progressively the rate of movement of aerated water over steel up to very high values. A point was reached (confirming earlier work of Heyn and Bauer) when the increase of corrosion that we have just considered gave place to falling values; by increasing the velocity still further, Friend succeeded in obtaining complete inhibition of corrosion, the specimen remaining bright and unrusted. This phenomenon is readily reproducible in the C.R.L. rotor apparatus. In the light of present knowledge, the explanation almost certainly lies in the fact that increasing speed of movement is able to stimulate not only cathodic depolarisation by which the rate of attack is increased—within definable limits—but also anodic polarisation which, small at first, at higher speeds controls the process and ultimately produces an invisible passivating film of oxide. Under stagnant conditions the replenishment of oxygen to the metal surface will clearly be more readily effected the thinner the intervening layer of water—assuming activating agents to be absent. In the limit, the water film becoming progressively thinner, we reach the true air-formed film, i.e., the film which forms spontaneously when a metal is exposed to air.

Breakdown of Films: Critical Humidity: Influence of Atmospheric Pollution

When we come to consider the breakdown of the invisible primary film—leading to corrosion as ordinarily understood—what is no doubt the outstanding example is provided by iron and steel. Figure 3 epitomises the results of experiments on the effects of progressively increasing relative humidity on the corrosion of iron specimens with and without the presence of atmospheric pollution (" inoculating " solid particles and traces of sulphur dioxide were used in my experiments described in the " Transactions of the Faraday Society " in 1935). At relative humidities of less than *ca.* 60 per cent. there is no visible change, whether the air is polluted or not; it is apparent that we are here concerned predominantly with film formation. Within the critical humidity range (60-80 per cent. R.H.) some rusting occurs and the film is obviously breaking down. When the critical humidity range is exceeded there is a relatively enormous increase in the rate of

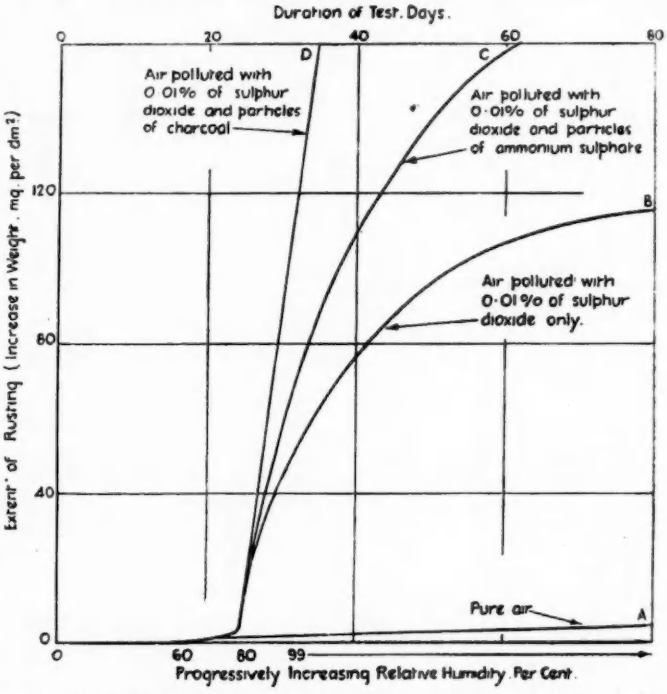

Duration of Test. Days.
Air polluted with 0·01% of sulphur dioxide and particles of charcoal
Air polluted with 0·01% of sulphur dioxide and particles of ammonium sulphate
Air polluted with 0·01% of sulphur dioxide only.
Pure air
Extent of Rusting (Increase in Weight. mg. per dm²)
Progressively Increasing Relative Humidity Per Cent.

Fig. 3. Critical humidity. Influence of humidity and atmospheric pollution on the rusting of mild steel.

corrosion, provided only that traces of pollution are present, the actual extent of rusting depending upon the nature of the pollution (Curves B, C, D). In pure air (Curve A) there is, in marked

Corrosion of Metals—continued

contrast, no sensible increase and the amount of rusting continues to be trivial, although the relative humidity is finally maintained at 99 per cent.; Curve B shows the effect of contamination by sulphur dioxide alone; Curve C the *additive* effect produced by introducing particles of ammonium sulphate, a typical constituent of ordinary (solid) atmospheric pollution. The most remarkable example of gaseous and solid pollution acting conjointly is provided by particles of charcoal. Intrinsically neutral, these are without action so long as the air is otherwise pure, the corresponding curve being coincident with Curve A. In the presence, however, of the small concentration of sulphur dioxide the effect (Curve D) transcends that of the intrinsically reactive ammonium sulphate in like circumstance. It is clear that the action of the charcoal particles must be primarily physical, locally increasing the concentration of sulphur dioxide by absorption; there would seem to be little doubt that a similar function may be played by carbonaceous particles in ordinary atmospheres in which, as in the experiments, gaseous pollution is represented by the presence of sulphur dioxide. It follows from a consideration of these curves that at high relative humidities (representative of service conditions over long periods in this country) the controlling factor is provided entirely by the state of purity of the atmosphere. The bearing of these results upon accelerated tests for atmospheric corrosion will now be apparent. Work in this field is being pursued at Chemical Research Laboratory; a method involving the use of increased concentrations of sulphur dioxide and rather higher temperatures has recently been described.

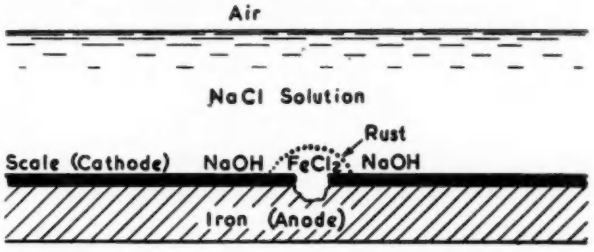


Fig. 4. To illustrate typical mechanism of "pitting."

Distribution of Corrosion

Having attempted to review some of the more salient features of atmospheric and immersed corrosion, I propose—before passing to a brief consideration of corrosion underground—to offer a few remarks about the way in which corrosion may be distributed on or in the metal. The simplest case is that of corrosion distributed uniformly over the surface with uniform depth of penetration into the metal. This is also the least dangerous case; indeed, unless æsthetic considerations or dimensional changes are important it rarely constitutes a serious problem in service. Local sed corrosion, particularly in natural waters or neutral solutions, may arise from the presence of a film or scale that is capable of functioning as a cathode when the underlying metal is exposed at any point. The dangerousness of the situation arises from the fact that oxygen reaching a large "catchment" area of the metal surface that is functioning cathodically may directly contribute to the corrosion at the small anodic area; the cathodic area is protected, but only at the expense of augmenting the attack elsewhere, the depth of penetration being correspondingly increased. This is the normal explanation of "pitting", which, depending on the thickness of the section, may lead to more or less rapid perforation (see Fig. 4).

An important corollary is the part which the distribution of dissolved oxygen may play, either in determining the efficiency of the cathodes the position of which is decided by other causes, or influencing the actual distribution of anodes and cathodes. This is the basis of the well-known "Differential Aeration Principle" associated with the name of Dr. U. R. Evans, by whose work it was largely established. As we have seen, in neutral solutions corrosion is essentially a function of oxygen supply, but this is required and used only at the cathodes. The differential aeration principle states that cathodic areas will be encouraged where the concentration of oxygen is greatest, and, paradoxically, anodic places (where metal is attacked) will tend to flourish where the oxygen concentration is least. As was shown, however, by Bengough and Wormwell, in solutions of alkali salts the effect of oxygen distribution is in fact exerted in virtue of its effect on the distribution of cathodic alkali. Initial starting centres may be innumerable, but the lateral spreading of alkali determines which persist and which are "stifled".

Anærobic (Microbiological) Corrosion

These examples of the graphitic corrosion of cast iron deeply immersed in the sea—under conditions in which the rate of oxygen supply must be excessively small—may well occasion surprise if one recalls the virtual absence of corrosion that is normally associated with such conditions. Allowance must naturally be made for the time factor: i.e., even the smallest rate of oxygen supply might be expected to produce tangible results if sufficiently long sustained. Nevertheless, there are good reasons for believing that the anomaly is genuine and that a more fundamental cause is responsible. As we shall see in a moment, corrosion at normal rates, in neutral solutions and without hydrogen evolution, has in fact been demonstrated in the complete absence of dissolved oxygen through the intervention of anærobic bacteria of the sulphate-reducing type; these organisms are known to flourish within certain areas of the sea bottom, and are referred to by W. J. Copenhagen in a report to the South African Department of Commerce in 1934. What is of greater economic significance is the fact that they also flourish in many impervious clays in which vast aggregate lengths of metal pipe systems are laid. This brings us to the subject of underground corrosion with which we can conveniently consider the associated microbiological factors.

Underground Corrosion

This problem is one of very considerable economic importance. For example, it has been estimated that the annual loss due to corrosion of the 450,000 miles of buried pipelines laid in the U.S.A. is of the order of £30,000,000. Available data show that in England and Wales there are 80,000 miles of water mains alone, which—making due allowance for probable errors involved in a *pro rata* conversion—leads to a corresponding figure of £5,000,000. So far as this country is concerned, there is overwhelming evidence that the problem is very largely confined to pipes embedded in waterlogged but otherwise impervious clay. Corrosion of cast iron takes the form of "graphitisation", perforation of a water main resulting when this extends to the thickness of the pipe wall at any place. This has been known to occur even within a year, and failures after five to ten years are common. We have the paradox therefore that this virulent attack is associated with conditions which, in the light of principles so far discussed, should lead to freedom from corrosion, i.e., they favour the exclusion of the oxygen which, in ordinary neutral environments, is necessary for cathodic depolarisation. An explanation of the paradox was suggested in 1934 by the Dutch worker, Von Wolzogen Kühr, in terms of the possible action of anærobic sulphate-reducing bacteria, *vibrio desulphuricans*; on this view, the organisms, by acting as "hydrogen acceptors," provide a mechanism for the disposal of cathodic hydrogen (cathodic depolarisation)—a role normally filled by atmospheric oxygen. Some of the earliest work in this field was carried out at Chemical Research Laboratory by H. J. Bunker and his colleagues, and further investigations are now being pursued intensively by Butlin, Adams and Thomas. Experiments in neutral solutions, oxygen being rigorously excluded, showed that corrosion occurred only in the presence of the bacteria. In the sterile medium the specimens remained bright; inoculated, corrosion proceeded with pitting of steel specimens and characteristic "graphitisation" of cast iron. The views of Von Wolzogen Kühr are thus confirmed—at least, in principle. It is clear that the function of the bacteria must be, primarily, that of depolarising the cathodic reaction—i.e., providing for the disposal of electrons that would otherwise accumulate in the cathode. But uncertainty still exists whether sulphate simply takes the place of oxygen in ordinary ærobic corrosion under neutral conditions.

Corrosion of Metals—*continued*

It is unfortunately true that all the conditions for microbiological corrosion—exclusion of oxygen, presence of bacteria, of sulphate, and of other factors favourable for their growth—are provided by the majority of clay soils. Observations in the field have abundantly confirmed the conclusions reached from laboratory experiments. Invariable symptoms and valuable diagnoses of the microbiological corrosion of buried metal systems are provided by the obvious presence of hydrogen sulphide when the system is first opened up, the local blackening of the soil due to the presence of ferrous sulphide, and the greatly increased concentration of bacteria in the immediate neighbourhood of the corroding metal. The investigations are continuing with the active and valuable co-operation of various water and gas undertakings and other public bodies.

Preventive Measures

From the general principles surveyed in the first lecture, we turn now to consider rather more closely the field of corrosion prevention. Again, however, bearing in mind the wideness of the field and the short time at our disposal, I propose to place the emphasis on principles rather than details, tarrying here and there to deal with some of the more recent developments or matters of more topical interest. Details of well-established processes can, in any case, be readily obtained from the usual literature sources. The general scheme that I propose to follow is set out in Table II.

TABLE II: SCHEME OF PREVENTIVE MEASURES.

I **Methods based on Modifications of Design or Procedure.**
- (a) Factors connected with design of structures.
- (b) Factors connected with surface condition.
- (c) Cathodic protection.

II. **Methods based on Modification of Environment.**
- (a) Water-treatment (pH control, de-aeration, etc.).
- (b) Corrosion inhibitors for acid and neutral solutions.
- (c) Corrosion inhibitors for wrappings and temporary protectives.
- (d) Prevention of corrosion in enclosed air spaces.

III. **Methods based on Modification of Metal.**
- (a) Influence of purity.
- (b) Corrosion-resistant alloys.

IV. **Methods based on Protective Coatings.**
- (a) Natural and artificial films or coatings of reaction products.
- (b) Paint and other organic coatings.
- (c) Metal coatings.
- (d) Miscellaneous coatings.

Professor Vernon then proceeds to consider each preventive method in turn. His remarks upon cathodic methods are alone reproduced, but in full.—(Editor.)

Cathodic Protection

So far we have considered what may be called the more "passive" methods of avoiding corrosion. We turn now to the much more active method (illustrating, par excellence, the control of corrosion by control of the corrosion mechanism) of cathodic protection. In effect, this comprises the application of a counter-EMF opposing the EMF respon ible for corrosion and rendering the whole of the structure cathodic. Thus, if (Figure 5) A and C represent schematically the anodes and cathodes of a system undergoing corrosion, the A zones corrode because they continually provide electrons to make good the deficiency of electrons in the C zones. If now we provide an external (auxiliary) anode AA (i.e., an external source of electrons) corrosion will cease if the supply of electrons from AA to C is equal to that previously forthcoming from A—in other words, if the original cathodes are "polarized" to the same electronegative potential as the original anodes. Any further increase in the superimposed EMF will further depress the joint potential of the original A and C areas, i.e., the whole structure will become "more cathodic". A sufficient cathodic current density may be impressed upon structures of iron or steel by the use of external anodes of magnesium, aluminium or zinc, the anode undergoing "sacrificial corrosion". Alternatively, anodes of scrap iron may be used, the necessary EMF being obtained from external generators. The former method, as represented by the use of zinc protector blocks on ships' hulls, is of long standing, having been suggested (originally for the protection of the copper sheathing of warships) by Sir Humphry Davy. In recent years considerable attention has been given to cathodic protection by controlled currents. In seawater, work at the Chemical Research Laboratory and independent work in the U.S.A., have shown that, provided a sufficiently high current density is applied to the cathode at the start, this can subsequently be reduced to a very small "maintenance value". This is possible because the alkali produced at the cathode precipitates a calcareous protective coating over the whole area. In the application of cathodic protection, due regard should be given to design factors. For the protection of large steel water-tanks the method is obviously well suited and is finding considerable application. At the other extreme it is difficult to apply (for reasons not difficult to see) over the *interior* of a water tube (e.g., condenser tube) and errors in this respect have been made in the past.

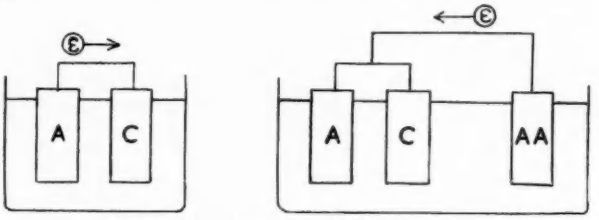


Fig. 5. To illustrate cathodic protection.
A=Original anode; C=Original cathode (schematically representing anodes and cathodes in same system).
AA=Auxiliary (external) anode.

For the protection of buried pipelines, cathodic protection is being successfully applied on a very large scale in the United States, having been taken up by the large oil companies, refineries and gas-transmission corporations. In this country the method does not appear so far to have been adopted to any appreciable extent, although developments are in progress and more extended use may be expected. For the long pipelines of America externally generated EMFs appear to be favoured, but the indications are that in this country sacrificial anodes will prove to be more expedient. In either case, the method does not dispense with the use of protective coatings, to which it may be regarded as supplementary, taking care of weak places in the (usually bituminous) coating or places where, as frequently happens in service, the coating has become damaged during the laying of the pipes; in this way excessive consumption of the sacrificial anode or of the external electrical energy is avoided.

Port of Leith Retirement.

Mr. T. A. S. Fortune, O.B.E., M.I.C.E., M.Inst.T. retired from the position of general manager, secretary and chief engineer to the Leith Dock Commission on November 15th last.

Mr. Fortune joined the Commissioners' staff over 40 years ago, and has, in association with his predecessors, and later while in charge, been responsible for many alterations and improvements to the Port of Leith. He is one of the joint engineers responsible for the deep-water quays at present being constructed in the Western Harbour at a cost of over £600,000 for Messrs. Joseph Rank, Limited's, new flour mill.

He has been a member of committees of the Dock and Harbour Authorities' Association and the National Association of Port Employers. During the war he was A.R.P. Controller of the Docks and vice-chairman of the A.R.P. Committee of the Edinburgh and Leith Chambers of Commerce.

Mr. Fortune, who received the O.B.E. this year, is a member of the Institution of Civil Engineers, a Member of the Institute of Transport, and also a Member of the French Institution of Civil Engineers.

Model Experiments on the Belgian Ports of the North Sea

By L. BONNET & J. LAMOEN*

(*conclued from page 205*)

The Ostend Harbour Experiments

The reduced model experiments on the Port of Ostend were undertaken by the Authors at the request of the Ministry of Marine to examine a proposed improvement of the entrance channel, advanced by Commandant Timmermans. The intention of the proposal was to facilitate the traffic of the Ostend-Dover mail boats by the widening of the entrance channel (see Fig 21). The existing channel is very narrow, being only about 380 feet wide between the timber jetties. The vessels enter regularly every day, in all weathers; after making a wide sweep in the offing, they enter stern first under their own power, proceeding thus upstream in a yet narrower channel for about 1,500 yards.

The Timmerman's proposal was to demolish the east jetty and reconstruct it about 200 feet further to the east and parallel to the west jetty. The western jetty was to remain in its existing state, with the exception of an increase of width at the head of about 30 feet. These entrance jetties are constructed of braced timber piles with open timber decks, over low pitched rubble moles which are submerged at high tides. The east jetty from the root to the head is about 450 metres long, while the west jetty is about 600 metres long.

Fresh Water Entering Port

The rain water drainage of the hinterland is carried into the port by the Bruges-Ostend Canal and the Noord Eede. There are four controlled barrages, or sluices, at the head of the port, but there is no continuous river flow through the harbour. The water of the Bruges-Ostend Canal is discharged into the port by four pipes having a total wetted sectional area of 15.16 sq. metres, and for abnormal floods a beam sluice 4 metres wide with its sill at 0.66 m. is used. The normal water level of the canal is (+4.05 m.), but at the time of heavy flood discharges it is reduced to (+2.80 m.) at Sas Slijkens. The maximum discharge recorded of this canal was 2,550,000 cubic metres per tide. At low tide the level of the canal falls to (+2.80 m.), when the delivery reaches 100 cu./m. per second with sluices full open. When the tide rises so does the level of the canal, and at (+3.50) the discharge is nil. At this point all sluices are closed until the tide is on the ebb. In the exceptional case where all the sluices are open between tides for 8½ to 9 hours, the discharge can be approximately represented in function of time by a semi-circle where the maximum ordinate is the maximum intensity of discharge thus:

$$3.14/4 \times 3{,}600 \text{ secs.} \times 9 \text{ hrs.} \times 100 \text{ m}^3/\text{sec.}$$
$$= 2{,}550{,}000 \text{ m}^3 \text{ per tide.}$$

However, when the four discharge pipes only are used, the discharge varies parabolically in function of time, so that the total volume discharged is given by:

$$2/3 \times 3{,}600 \text{ secs.} \times 8.5 \text{ hrs.} \times 70 \text{ m}^3/\text{secs.}$$
$$= 1{,}425{,}000 \text{ m}^3 \text{ per tide.}$$

The maximum discharge per tide from the Noord Eede is 216,000 m³; thus the maximum total discharge of fresh water into the port from the two main sources is 2,550,000 + 216,000 = 2,766,000 cubic metres per tide, but the more usual discharge is 1,425,000 + 216,000 = 1,641,000 cubic metres per tide.

Taking this figure, we get for the maximum discharge per day into the Ostend harbour:

$$1{,}641{,}000 \times \frac{24}{12 \text{ hrs. } 25 \text{ min.}} = 3{,}150{,}000 \text{ m}^3$$

or in round figures, 100,000,000 cubic metres per year, which assumes that the maximum discharge is 10.4 to 13.8 times the daily average.

Silting in the Port

The laboratory was informed that the mud content of this fresh water was about 0.1 per cent., which would mean 100,000 cubic metres of silt per annum of feeble density, did none pass out to sea.

The volume of tidal sea water which enters the port per year is approximately $1{,}152 \times 10^6$ cubic metres. The authors give the figures of 10 grs. to 1,000 grs. of dry mud per cubic metre of sea water, varying from low to high water content. The deposit of mud in the Ostend harbour, however, proceeds slowly, which probably accounts for its low specific density, 1.20 kg. to 1.25 kg. per litre. Near the entrance heads, where the proportion of sand is considerable, the specific density is 1.6 to 1.8 kg. per litre.

* "*Etude des Ports Belges de la Mer du Nord*" *Essais sur modeles reduits.* Extracts from the *Annales des Travaux Publics de Belgique.*

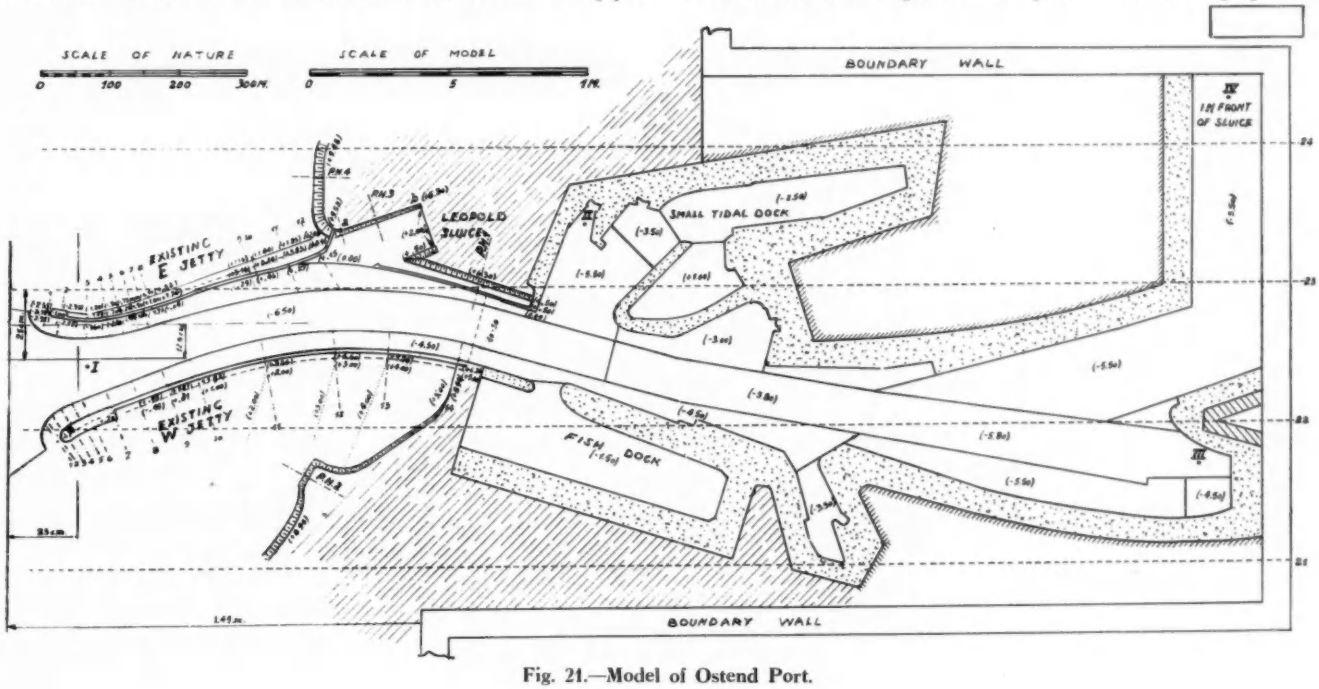


Fig. 21.—Model of Ostend Port.

Model Experiments on Belgian Ports—continued

Let δ = specific weight of a litre of mud deposit

X = volume of dry mud (without voids) contained in a litre of mud deposit

1.025 = the weight of a litre of sea water

2.6 = weight of a litre of dry mud (without voids)

g = the weight of dry mud per litre of mud deposit

$$\text{then } \delta = (1-X)\ 1.025 + 2.6\,X$$

$$\text{and } g = 2.6\,X = \frac{2.6\ (\delta - 1.025)}{(2.6 - 1.025)}$$

then for $\delta = 1.20$ kg. litre, $g = 0.288$ kg. per litre

$\delta = 1.60$ kg. litre, $g = 0.950$ kg. per litre.

Laboratory tests confirmed these results.

Assuming that the sea water entering the port contains 250 gr. of dry silt per cubic metre and that all of it is deposited, then the yearly silting would be:

$$\frac{1{,}152 \times 10^6 \times 0.250}{1{,}000 \times 0.288} = 1{,}000{,}000 \text{ cubic metres.}$$

Hence the total silting in the port would in one year have a volume of:

from sea water 10×10^5

from fresh water 10×10^4

= 1,100,000 cubic metres.

According to the authors' experience in their laboratory at Antwerp, the supply of fresh water into a port gives rise to an incursion of sea water along the bottom two or three times as great in volume as that of the fresh water. Assuming this to be only twice as great, we have an added deposit of mud equal to:

$$1{,}000{,}000 \times \frac{2 \times 100{,}000{,}000}{1{,}152{,}000{,}000} = 170{,}000 \text{ m}^3$$

which then brings the total silting per annum to 1,270,000 cubic metres, of which 270,000 m³ is due to the fresh water. This latter figure is probably too high; however, the contention of the authors is that the direct influence of the fresh water supply on silting is small in comparison with the influence of sea water. The average yearly dredging of the port is about 900,000 m³, hence one may safely deduce that a considerable quantity of silt passes out to sea with the ebb tide. This has been confirmed by the Coastal Service authority, who report that the silt brought into the port does not completely deposit itself there. If the depths were increased, it could happen that a diminution of the quantity of silt carried into the sea might take place. It remains none the less true that the maximum quantity of silting would be equal to the total quantity of silt entering the port from all sources, which quantity has been estimated at 1,270,000 cubic metres annually. The following table of dredging between the years 1935-1939 shows that, although the harbour was deepened, it was not followed by an increase of silting.

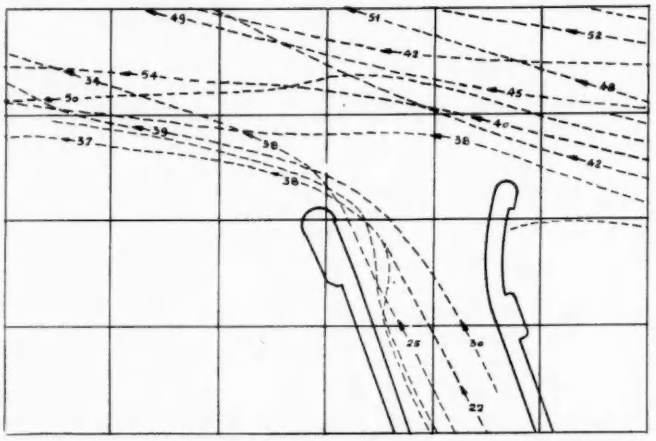


Fig. 22.—Ebb currents. Directions and velocities outside of Ostend Harbour. Model reproducing actual state. Velocities in centimetres per second natural.

DREDGING OF PORT.

Year	Volume of harbour water below the reference datum 0.00 m.	Volume dredged in cubic metres	Total volume of silting in cubic metres
1935 ...	1,613,000		
		1,093,000	1,020,000
1936 ...	1,686,000		
		988,000	1,022,000
1937 ...	1,652,000		
		1,528,000	1,383,000
1938 ...	1,819,000		
		929,000	930,000
1939 ...	1,813,000		

The authors draw attention to the differences of the silting phenomenon of Zeebrugge and Ostend, pointing out that in the former port the deposited silt contains 0.8 kg. of dry mud per litre, whereas in the latter it is only 0.288 kg. per litre. Thus a similar thickness of mud from one or other of the ports has a different significance. The mechanism of silting is also different. At Zeebrugge the large eddy to the east of the port during flood is the main factor, whereas at Ostend it is mainly due to the settling out of the suspended grains of silt from the entering sea water. It would appear highly probable that the water depths of the port of Ostend could be increased, within reasonable limits, without any considerable extra dredging, in other words, neglecting the influence of a bottom current provoked by the entry of fresh water at the head of the port, the amount of silting at Ostend is independent of the depth of the port. This, of course, is not applicable to the entrance channel, for here there is evidence of eddy formation provoked by the friction of the passing tidal sea currents on the waters of the entrance channel. However, since the annual silting in this zone is only 90,000 cubic metres, the addition of this amount cannot lead to any considerable increase on the total dredging of some 1,000,000 cubic metres for the port, including the entrance channel.

Again, the annual volume of dredging at Ostend is almost independent of the form of the entrance channel, so long as the latter remains long and narrow, as the existing entrance, or in the proposed Timmerman modification. In the model experiments, particular attention was directed on the currents at the entrance heads, as much for the safety of navigation as to preserve the silting or sand bar formation within reasonable limits. In this respect, the formation of eddies at the entrance must be prevented, since these giratory movements cause silting in their immediate neighbourhood, whereas modifications to the piled jetties or low rubble moles lead to changes in the regimen of deposit, they are confined to the entrance channel zone, and do not spread into the whole tidal port.

Salinity of Port Waters

The salinity of the port waters taken from several points was analysed and the following table gives a few only of the results. For the figures referring to the July, 1938, tides there was no discharge of waters from the neighbouring polders into the port, but there is always a certain amount—leaks by the sluice gates, etc. At low and high tides the salinity diminishes in proportion to the distance from the sea. The December, 1939, figures were obtained when the harbour was inundated by fresh water from the interior of no less than 3,000,000 cubic metres in 12 hrs. 25 mins., a volume which is 60 per cent. greater than the total volume of sea water which enters and leaves the harbour in one tide cycle.

The positions at which the samples of port water were taken is indicated in Fig. 21: note the salinity differences in the vertical planes.

Model Experiments on Belgian Ports—continued

SALINITY OF PORT WATERS.

Ostend.			Low Water.		July, 1938.
Position		Bottom level metres	Level at which samples were taken	Salinity gr. per litre	Average Salinity in the vertical section
I	...	−5.60	+0.60	26.9	30.2
			−3.10	31.6	
			−4.60	32.1	
III	...	−4.20	+0.70	15.2	25.7
			−1.70	30.4	
			−3.20	31.6	
			High Water.		
I	...	−5.60	+4.20	26.9	30.4
			−0.70	32.1	
			−4.60	32.1	
III	...	−4.20	+4.40	21.6	27.7
			+0.10	29.5	
			−3.20	32.1	
			Low Water.		**December, 1939.**
I	...	−5.60	+0.50	8.1	17.5
			−2.50	16.3	
			−4.60	28.0	
III	...	−4.70	+0.30	4.6	9.9
			−2.00	7.6	
			−3.70	17.5	
			High Water.		
1	...	−5.60	+4.20	2.3	16.9
			−0.40	20.4	
			−4.60	28.0	
III	...	−4.70	+4.20	4.6	19.2
			+0.30	25.7	
			−3.60	27.4	

Summary

A general conclusion which emerges from the preceding argument is that the ports on the Belgian coast can, according to their form in plan, be classed in two categories:

(a) the ports where an increase in depth of water is accompanied by an increase of silting, such as Zeebrugge;

(b) the ports where an increase of depth does not lead to any considerable increase of deposits, such as Ostend and Nieuport.

Experiments on Currents in the Model

The model of the Port of Ostend was constructed to the following scales:

horizontal scale = 1/n = 1/400
vertical scale = 1/m = 1/60
giving a distortion of 400/60 = 6.67.

As in the Zeebrugge experiments, the authors took a direct line of empirical procedure where it was found convenient, as for example, the scale of velocities was fixed at 1 : 2.25, that is, the model velocities were to be multiplied by 2.25 to give the real velocities in place of $V = v\sqrt{m} = v \times 7.74$. The experiments on currents were effected with a permanent flow representative of the tidal phase. For the flood the level of the water (+ 4.69 m.) in the model and the amount of make-up were maintained constant, simulating the conditions at high water springs. A similar procedure was adopted for the ebb, which reaches a maximum current velocity 0.5 hours after high water when the level of the tide is (+ 0.97 m.).

For the ebb tide the conditions made it necessary to supply water from the head of the harbour, at the time of tide level when the level of the waters descend at the rate of 0.87 m. per hour, which over the port area of 40 hectares represents:

40,000 × 0.87 = 348,000 cubic metres per hour
or 97 cubic metres per second.

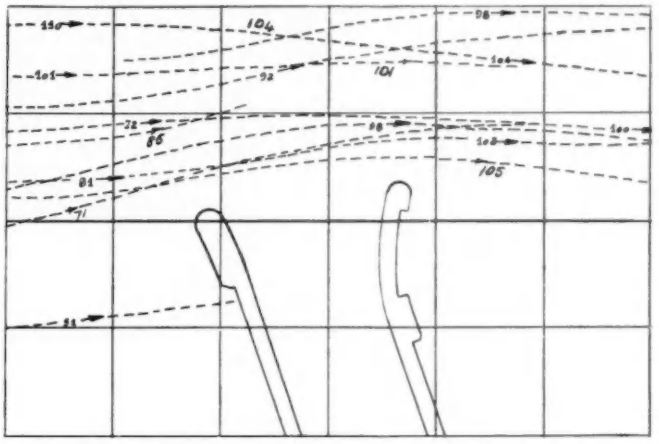


Fig. 23.—Flood current. Directions and velocities outside Ostend Harbour. Model reproducing actual state. Velocities in centimetres per second natural.

Assuming that the discharge is uniform over the wetted section of the entrance channel, which at this time of tide has a cross-sectional area of 550 m², then the average velocity of discharge out to sea is 97/550 × 100 = 18 cms. per second.

The actual measurement of the natural current in the entrance channel at the corresponding time of tide gave 35 cms. per second. This divergence, the authors suggested, was due to the concentration of the fresh water at the surface; nevertheless, for the experiments, they decided that 35 cms. per second should be realised in the entrance channels. To attain this, three litres of water were supplied to the model at the head of the port. The sea ebb currents outside of the harbour were obtained by supplying the model with 55 litres per second, with the water level maintained at (+ 0.97 m.). For the flood currents the model was supplied with 248.7 litres per second and the water level maintained at (+ 4.69 m.). The general direction of these currents and their velocities are shown in Figs. 22 and 23.

In the experiments concerning the sea currents of ebb and flow, the model form of the entrance jetties was satisfactory, but when it became necessary to make a detailed investigation of the currents in the harbour channel, some expedient to simulate the resistance of the transverse bracings, etc., to the flow of the currents was deemed indispensable for good results. To the small scale of the model it was impossible to reproduce the existing features, but the authors found that the problem was resolved by draping the outer sides of the model jetties with metal mesh, as indicated in Figs. 24 and 25. This remedy, however, entailed a virtual reduction of the section of flow of the model, which was adjusted by reducing the flood water supply from 248.7 litres to 232 litres per second. For the ebb a similar reduction was not required, as the water level at the time fixed for the experiments is very low, and there is therefore little effective resistance by the jetties to the outward flow.

The velocities and directions of the surface currents were traced by the use of small floating lighted candles photographed at convenient intervals of time, whereas the direction of the bottom currents were principally observed by means of little moistened balls of blotting paper. The bottom velocities could not be determined, since the balls were not in suspension and were influenced by friction on the bottom. For the study of the bottom currents within the harbour, it was decided that a truer appreciation of the actual adverse conditions would be attained by suppressing the supply of 3 litres at the head of the port, since, if there was any tendency for the formation of eddies, on a vertical axis, to form at the entrance, this suppression would make them more apparent. The surface currents were also investigated without any water supply in the port. The currents traces are reproduced from the photographs without correction, thus there are conical projections which slightly modify the representation in plan, nevertheless they are sufficiently exact for the purpose.

Model Experiments on Belgian Ports—continued

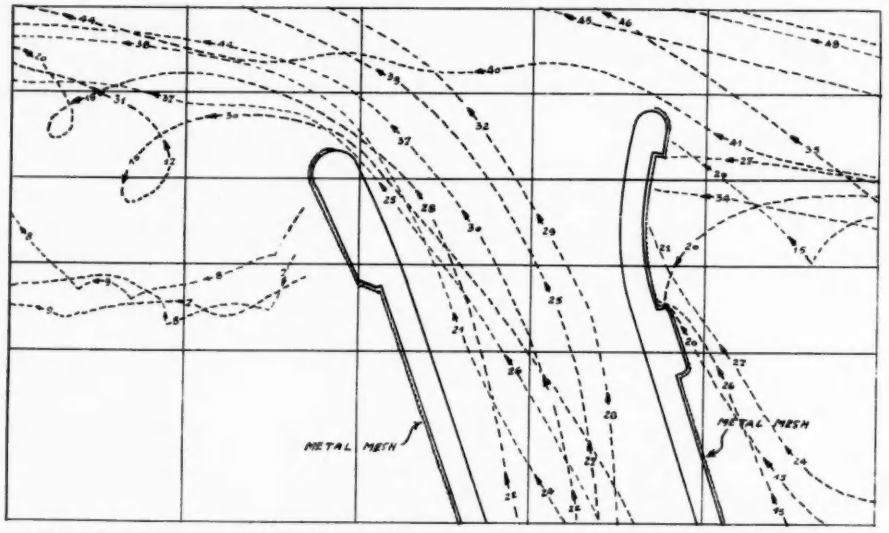


Fig. 24.—Ebb currents. Directions and velocities about the Entrance Channel. Model reproducing actual state. Velocities in centimetres per second natural.

Experimental Results

The results of the experiments led to the following observations:

For the flood tide—

No eddies on the water surface.

The presence of an eddy on the bottom, which carries sand and silt into the entrance to the port.

For the ebb tide, with water supply at the head of the port—

No eddies on the surface.
No eddies on the bottom.

For the ebb tide, without water supply in the port—

No eddies on the surface.
Slight eddy on the bottom.

Experiments on the Timmermans' Project

The proposed new jetty was realised in the model by fabricating it with metal mesh on both sides, which was considered equal in behaviour to a piled superstructure and a low rubble jetty. The surface currents for the flood (Fig. 26) were obtained with a sea water supply of 232 litres per second and with a water level of (+ 4.69 m.) with no additional water supply in the port. The ebb tide currents (Fig. 27) had a sea water supply of 55 litres per second and 3 litres per second at the head of the port with a water level of (+ 0.97 m.). The observations were:

For the flood tide—

No eddies on the water surface.
Strong eddy on the bottom.

For the ebb tide, with water supply at the head of the port—

No eddies on the surface.
No eddies on the bottom.

For the ebb tide, without water supply in the port—

No eddies on the surface.
Slight bottom eddy.

It is to be observed that the currents in this project do not differ sensibly from the actual situation. In order to suppress the eddy on the bottom, which manifests itself at the time of flood, the western jetty was prolonged 82 metres seaward in a model representing the existing situation. The tests gave the following observations:

For the flood tide—

No eddies on the surface of water.
No eddies on the bottom.

For the ebb tide, with water supply at the head of the port—

No eddies on the surface.
No eddies on the bottom.

For the ebb tide, without water supply in the port—

Eddy on the surface.
No eddies on the bottom.

It was therefore concluded that this project was more favourable than the existing state. A further trial with 64 metres extension gave very similar results. A still further trial was made with an extension of the western jetty by 40 metres on the Timmerman project, and the results showed that the extension was not sufficient to suppress the bottom eddy on the flood tide. It was apparent to the authors that it was necessary to maintain a certain relation between the prolongation of the western jetty and the width of entrance channel. The western jetty was therefore extended to 80 metres in the Timmerman project, with the result that only on the ebb tide without water supply in the port did a very slight eddy appear on the surface of the water. This favourable result led to another trial, in which the western jetty remained in its original state and the projected eastern jetty of the Timmerman proposal was shortened by 80 metres. The result was as follows:

For the flood tide—

No eddies on the water surface.
Strong eddy on the bottom.

For the ebb tide, with water supply in the port—

No eddies on the surface or on the bottom.

For the ebb tide, without water supply in the port—

An eddy on the surface.
An eddy on the bottom.

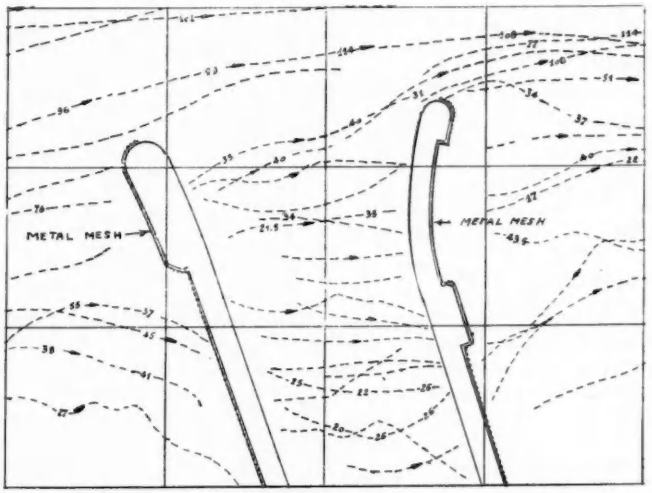


Fig. 25.—Flood current. Directions and velocities about Entrance Channel. Model reproducing actual state. Velocities in centimetres per second natural.

Model Experiments on Belgian Ports—continued

The strong eddy on the bottom at flood tide was no doubt due to the nearness of the deep water channel at the jetty head to the shallow waters of the beach to the east. This modification was therefore rejected.

To allay any doubt about the general applicability of the above experiments with constant depths of water for the flood and the ebb respectively, the authors decided on further tests at different levels with proportionate supplies of water to the model to equate for the state of the tide at which they would occur. The flood tide level was fixed at (+ 3.80 m.) and the sea water supply at 225 litres per second. The ebb tide level was fixed at (+ 0.50 m.) with a sea water supply of 54 litres per second and a fresh water supply of 2.9 litres per second at the head of the port. The resulting observations differed in no wise from those already recorded, which leads one to conclude that the results had the character of generality.

Experiments on Swell

In principle it was the same wave generating apparatus used for the Zeebrugge experiments. At the point A (Figs. 28 and 29) the waves were given an amplitude of from 4 to 6 centimetres and a wave length of 60 centimetres. To attain the degree of wave spending on the model jetties provided by the low rubble mole in nature, the space behind the metal mesh was filled with timber shavings, of which the degree of buoyancy was regulated in such a manner that the waves in penetrating the model entrance spread out and slackened. In this connection a very important point arises affecting all model reduction mechanism, dealing with liquid wave behaviour. The exaggerated vertical scale may produce, or tend to produce, as we saw in the Zeebrugge experiments, wave reflection instead of spending. In this particular case, the authors noticed that in the experiments of swell coming from the north-west, standing waves were formed at the Leopold sluice, between the points E and D on the east bank of the entrance. These do not occur in nature, or rather they are so small that they pass unnoticed, hence provision had to be made for the spending of the waves at this point. This is one of the defects of the distortion of scale and imposes on the experimenter the necessity of great care in the analysis of observations in which the factor of water depths enters.

From preliminary experiments, it was found that to approximate to the actual wave phenomena it was necessary to give the plunger of the wave generator 93 oscillations per minute, which produced 93 travelling waves per minute. If the frequency much exceeded

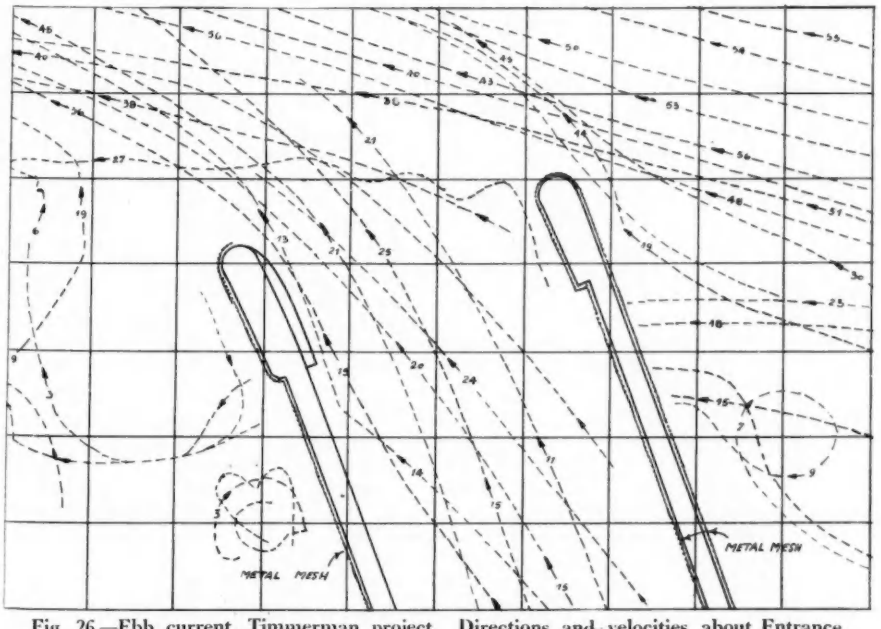


Fig. 26.—Ebb current, Timmerman project. Directions and velocities about Entrance Channel. Velocities in centimetres per second natural.

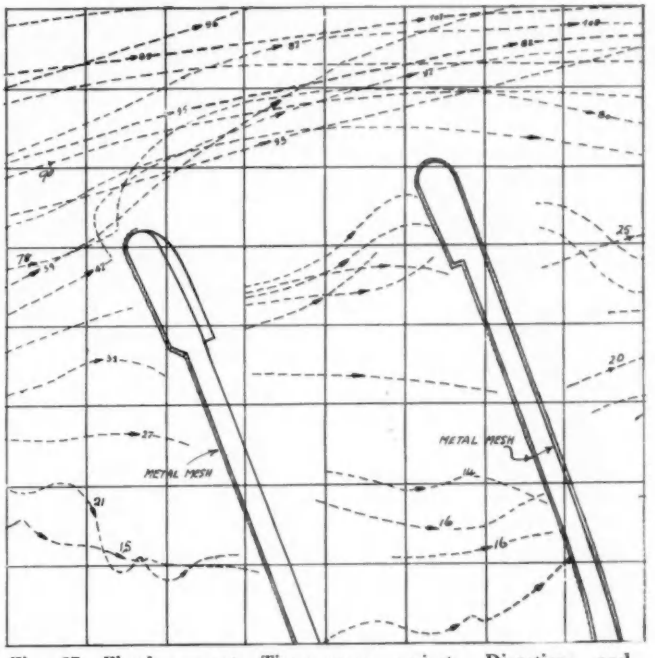


Fig. 27.—Flood current, Timmerman project. Directions and velocities about Entrance Channel. Velocities in centimetres per second natural.

this figure, then the production of wave phenomena changed suddenly. For slight amplitudes and low frequencies, travelling waves were produced, of which the frequency was the same as that of the plunger, and in which the crests of the waves were parallel to the axis of the plunger. On the other hand, if the amplitude, or the frequency, or both simultaneously were increased, the phenomenon of model travelling wave generation suffered a complete transformation and standing waves were produced, of which the frequency was double that of the plunger. The crests of these waves were normal to the travelling waves, and therefore also normal to the longitudinal axis of the plunger.

With an amplitude of 6.65 centimetres for the vertical oscillatory movement of the plunger, the swell in the useful part of the model was easily measured. The water surface for the wave experiments was fixed at (+ 3.40 m.) as, although this was not high water, it was at this state of the tide that the waves of actuality provided the greatest inconvenience in the entrance channel.

The measurement of the wave amplitudes was carried out with the aid of two needles with electric connections; one needle for the crest and one needle for the trough. These needles (Fig. 30) were placed close together and each was mounted on a bracket which carried vernier adjusting screws, allowing for vertical movement. Both needles were connected in their own circuits with a counter, similar to a telephone counter, and both were actuated by contact with water, which closed the electric circuit. The needle of the crest recorded by counting the number of times it came into contact with the water, whereas the needle of the trough registered the number of times it lost contact with the water. As a preliminary, the points of the needles were both set at the still water level and the wave machine put into action. The needles

Model Experiments on Belgian Ports—continued

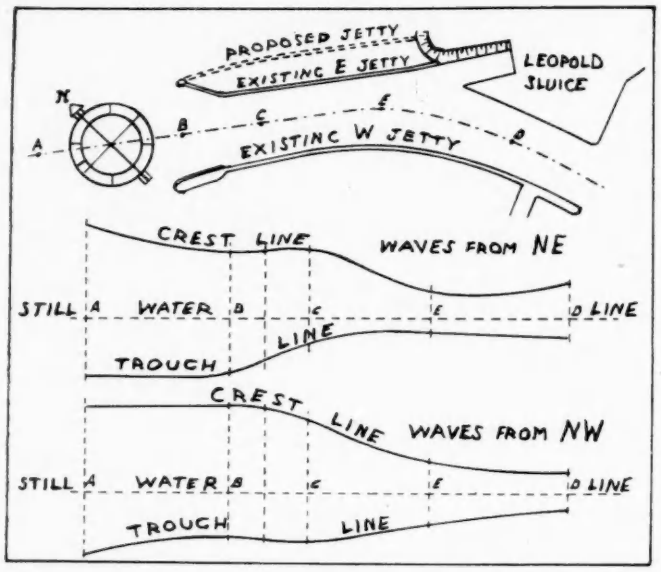


Fig. 28.—Wave reduction within the Entrance Channel. Model reproducing actual state.

then registered 93 contacts, or breaks, for the crests and troughs of the waves respectively. Following this, the crest needle was raised 1 m.m. and the trough needle lowered 1 m.m. and the number of contacts and breaks again registered. The procedure was repeated for various distances above and below the still water level and the counts noted. The records were plotted with the number of contacts, or breaks, as ordinates; the crest needle being considered positive and the trough needle negative. The displacement of the point of the crest needle from still water level was set off as positive abscissa, and the trough needle displacement as negative abscissa. A diagram was thus obtained, from which the amplitude of the wave was arrived at by taking the mean of the crest and the trough readings.

One found almost without exception that the crests of the waves rise to a greater height above the still water level than the trough sinks below it. The swell amplitudes of the entrance channel were measured in the manner above described at the points A, B, C, D and E (Fig. 28); the point A was taken as the "out at sea" wave of an amplitude of 100, as figured in the following table. At this point it was noted that the proportion of the wave above still water level was 58 per cent. of the full amplitude 100, trough to crest. The plots of the swell in the entrance channel, as given by the crest needle, is shown in Figs. 28 and 29. It will be noted that the Timmerman project shows the more rapid wave reduction and, very strangely, a deeper trough displacement in proportion to the amplitude. It is probable this latter feature is due to the spending effect of the east jetty.

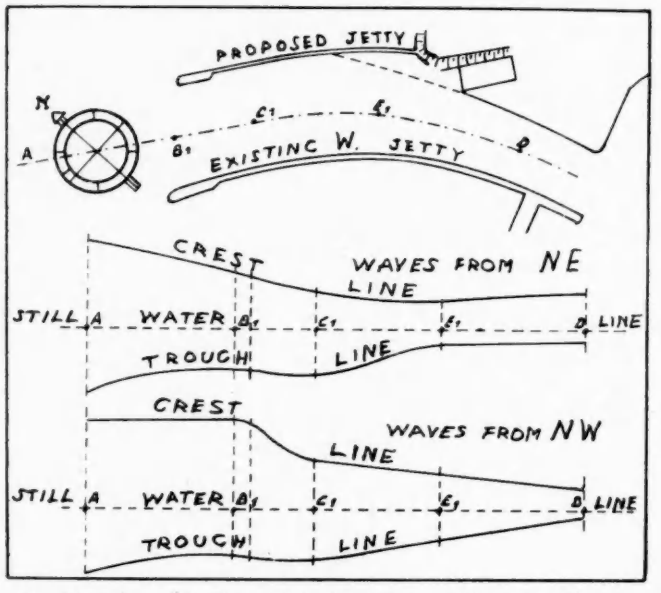


Fig. 29.—Wave reduction within the Entrance Channel of Timmerman project (model).

TABLE OF WAVE HEIGHTS.

In Nature and in the Models.

Condition	Waves approaching from	Points of Observation A	B	C	D	E	Remarks
Existing State Model ...	N.E.	100	82	64	27	36	Note (1)
Nature ...	N.E.	100	88	50	—	38	Note (2)
		100	80	60	—	50	Note (3)
Nature ...	N280W	100	57	100	—	20	Note (2)
		100	70	100	—	29	Note (3)
Existing State Model ...	N.W.	100	90	82	41	24	Note (1)
Nature ...	N.	100	—	90	—	20	Note (2)
		100	—	70	—	23	Note (3)
Timmermans Model ...	N.E.	100	64	55	27	33	Note (1)
	N.W.	100	88	65	42	18	Note (1)

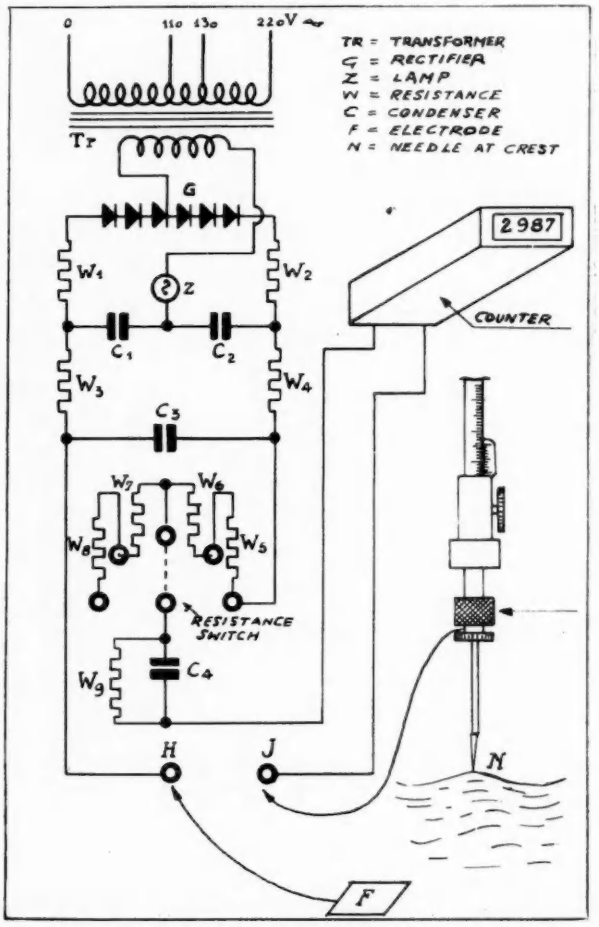


Fig. 30.—Device for electric recording of swell in model experiments.

Model Experiments on Belgian Ports—continued

Note (1): Provision of swell abatement at Leopold sluice. West and east jetties: the section of flow was reduced by the placing of metal mesh screen alongside of jetties —low rubble jetties. For the Timmerman project, a double metal mesh screen was used for the east jetty.

Note (2): Minimum amplitude of a series of observations.

Note (3): Maximum amplitude of a series of observations.

Conclusions

The conclusions of the authors were that the swell reduction and the silting in the harbour of the projected Timmerman scheme showed little or no difference to the existing situation. From the point of view of hydraulic improvement, the existing situation and the Timmerman project would be improved by the extension of the timber west jetty head some 80 metres seaward without any increase of length of the low stone mole over which the jetty is built.

The discharge of the fresh water from the interior into the port has no erosive or scouring action whatsoever; on the contrary, it adds to the silting of the port. The authors are definitely of the opinion that the old ideas of utilizing these fresh waters as sluicing aids for channel maintenance are illusory and suggest that it would be better to lead the waters to the sea by separate channels. They also contend that a port such as Ostend is better served by the preservation of a long, narrow channel, where the silting is due only to the material held in the sea water of the tidal cycle.

. . . . . .

The outstanding features of these model experiments are the practical methods adopted to achieve results related to the actual phenomena. Hitherto quite a number of similar experiments have been carried out on a too rigid academic adherence to mathematical interpretation. Such procedure can seldom reproduce successfully maritime phenomena which are much too complex to conform to rule. The wider one's experience of the fickle nature of sea coast conditions, the more one is inclined to treat each case of investigation of regime as independent and original. Naturally there are similarities, one with the other, and broad general principles become apparent, but the build-up of the whole local system of each different zone is as variable as human character. The authors, appreciating this distinction, investigated the model reactions with close regard to the actual natural mechanism of the full-scale phenomena.

There are, however, two very important points that could be further amplified. The details given of the full-scale and the model wave reduction within the harbours are very meagre. Maritime engineers would like to know more about the ranging in the zone of the shipping berths at Zeebrugge and Ostend. The other point is in connection with the recommended modification Lab. 8d of the Zeebrugge harbour. Have the authors investigated the effects on the shore line west of the mole, and to the east of the Heyst entrance channel under the conditions of the suggested project? Perhaps they have further data on these points.

R. R. M.

Erratum.

In the second instalment of this article, in the issue of "Dock & Harbour Authority" for November last, p. 205, column 1, the item No. 5 of the wave reduction table should read:—Lab. 8, with sloped walls.

The Distortion of Scales in Models with Loose Beds

By HERBERT CHATLEY, D.Sc., M.I.C.E.*

The convenience of distorted scales in hydraulic models with loose beds has been known since the time of Osborne Reynolds and it has long been realized that the contrast between the narrow deep runnels of tributaries and the wide shallow channels of main streams gave a natural illustration of such distortion.

2. Reynolds (Sci. Papers, Vol. II, p. 414) thought that the need to maintain turbulent flow in the model was the criterion for distortion (" exaggeration of scale "), but his formula

$$e = 0.09\sqrt{\frac{30}{H}\cdot\frac{v^3}{H^3}}$$ [foot units, H = tidal range ; vertical scale 1 in y]

does not appear to be reliable and his arguments for it are not very sound. Thus he assumes the applicability of the de Chezy formula (which is in fact inconsistent with distortion) and he assumes a kind of homomorphy of the " Reynolds Number " between the model and its prototype.

Furthermore it should be observed that the distortion relation may still exist between a model and its prototype when the flow conditions in the model are indubitably turbulent.

3. Gerald Lacey in 1934 (Min. Proc. Inst. C.E., Vol. 237, 1933-34, Pt. I., p. 421) put forward a formula for *regime* channels in incoherent alluvium:—

$$v = 4(2g)^{\frac{1}{4}} r^{\frac{1}{4}} s^{\frac{1}{2}}$$

This formula he has ever since maintained as valid and has expressed it in various equivalent forms. He holds that it is independent of silt-grade and approaches the value of a natural law. In India it has been much examined and although not sufficiently supported to be quite acceptable as universal it does seem to apply in many cases. Naturally some difficulty arises in the definition of regime since in natural channels discharge varies from day to day and from year to year.

From this formula a distortion rule for *similar* streams can be deduced as follows:—

(horizontal scale 1/x ; e = x/y)

$$\frac{1}{\sqrt{y}} = \left(\frac{1}{y}\right)^{\frac{2}{3}} e^{\frac{1}{3}} \text{ ; whence } e = \sqrt{y} = x^{\frac{1}{3}}$$

Lacey himself regarded his rule as generally cogent, but it is easy to see that small deviations from the basic Lacey rule may lead to different values of e and that $e = \sqrt{y}$ is also consistent with the following forms:

$$v \propto r^{\frac{1}{2}} \text{ ; } v \propto r^{\frac{1}{2}} s^{\frac{1}{2}} \text{ ; } v \propto r^{\frac{1}{3}} s^{\frac{1}{2}} \text{ ; } v \propto rs$$

and any intermediate ones $v \propto r^{\frac{\beta+1}{2}} s^{\beta}$

where β may have any value between 0 and 1.

4. Still another way of arriving at this formula $e = \sqrt{y}$ is to assume that the vertical component of the velocity is constant in similar systems.

If the longitudinal slope of the stream is S, the horizontal component of the velocity is

$$V_h = \sqrt{V^2 - (V_h S)^2}$$

and the vertical component is

$$V_h S = S\sqrt{V^2 - V_h^2 S^2} \text{ or } V_h^2 S^2 = S^2 V^2 - V_h^2 S^4$$

If S is a small fraction the last term can usually be neglected so that

$$V_h S = VS$$

If this is constant $vs = VS$ or $\frac{v}{V} = \frac{S}{s} = \frac{1}{e}$, or as $\frac{v}{V} = \frac{1}{\sqrt{y}}$

$$e = \sqrt{y}$$

If the silt grains are of uniform size (or of equal standard sizes, equally distributed) in both systems, in water of equal temperatures

*Paper presented at a Meeting of the International Association for Hydraulic Structures Research held in Stockholm, 7th—9th June, 1948, and reproduced by kind permission.

The Distortion of Scales in Models with Loose Beds—continued

they have the same terminal velocity, so that v_s is constant and in equal times the particles will descend equal distances from a horizontal plane, and in corresponding time $(t/T = 1/e\sqrt{y})$ the vertical distances will be in ratio

$$(v_s + vs).t/(v_s + VS)T = 1/e\sqrt{y}$$

so that if $e = \sqrt{y}$ the ratio is 1/y, i .e., in accordance with the scale.

This, however, implies that similarity of precipitation will occur when grains are of the same size and density if $e = \sqrt{y}$ but not necessarily when they are not of the same size and density, which does *not* agree with Lacey's condition of independence of silt grade.

5. If we abandon the regime condition and use some of the empiric rules for flow in alluvial channels we arrive at slightly different results for the distortion relation between similar systems.

Thus the Manning rule $v = \frac{1}{n} n^{\frac{3}{2}}s^{\frac{1}{2}}$

leads to a result, if n is constant, $e = y^{\frac{1}{2}}$

the Forchheimer rule $v = \frac{1}{n} . r^{0.7}s^{0.5}$ gives

$$e = y^{0.3}$$

and the Blasius condition that skin friction coefficient varies inversely as the fourth root of the Reynolds number gives

$$e = y^{\frac{1}{4}}$$

Lastly, the Chezy rule (which supposes skin frictional unit resistance to be independent of size and grain) gives

$$e = 1, \text{ i.e., zero distortion.}$$

The latter would be modified if empirical coefficients such as Kutter's were introduced, but this is irrelevant for the moment.

It thus becomes clear that either e is a function of the deviation of the channel resistance from the simple Chezy rule, or if it have a fixed form, the deviation of the channel resistance from the simple Chezy rule is a function of the distortion.

6. If a model is fed by natural rainfall and is placed on its prototype so that the run-off per unit area is the same for both, and the channels in both are running bank-full, then for the relative discharges (w, W, widths)

$$q/Q = 1/x^2 = \frac{va}{VA} = \frac{1}{\sqrt{y}} \cdot \frac{1}{xy}$$

so that

$$x^2 = xy^{\frac{3}{2}} \text{ or } x/y = e = \sqrt{y}$$

Note also that if $q/Q = \frac{1}{x^2}$, since $w/W = \frac{1}{x}$, $w/W = \left(\frac{q}{Q}\right)^{\frac{1}{2}}$

which is one of Lacey's empirical conclusions as to natural streams in alluvium.

7. Similarly in a tidal model if a wave length l is considered, the volume of the wave per cycle varies as hbl/t [h, H, wave heights, b, B. breadths] so that if a constant fraction of the wave flows over the bed in a cycle time,

$$q/Q = (hbl.T)/(HLB.t) = \frac{1}{yx^2} . e\sqrt{y}$$

and when $e = \sqrt{y}$ this equals $1/x^2$ so that the conditions in para. 6 recur.

8. There is, however, a source of danger in such reasoning, inasmuch as it does not at all follow that any two natural channels are "similar" systems. They may be (in which case $v/V = 1\sqrt{y}$) but equally well they may not be, even if (which is practically never the case) the bed material, the rugosity, the grain size and the charge are identical.

Lacey in 1929 already came to the conclusion that in regime *canals* of constant bed material the velocity varied as the square root of the hydraulic radius (Min. Proc. Inst. C.E., Vol. 229, 1929-30, Pt. I., p. 259), so that we could write

$$v = c^1\sqrt{r}$$

where c^1 is a "silt-grade factor," but Inglis and others have questioned whether c^1 is a constant over a wide range of dimensions. If it were so, for *similar* regime channels, by Froude's law

$$v/V = \frac{c^1\sqrt{r}}{C^1\sqrt{R}} = \sqrt{\frac{r}{R}}, \text{ i.e., } c^1 = C^1$$

In other words, similar regime channels should have identical silt grade conditions, which seems to lead to the unpleasant conclusion that similar channels cannot both be in regime unless the silt grade conditions are the same. This is, however, inconsistent with Lacey's $v \propto r^{\frac{1}{2}}s^{\frac{1}{2}}$ rule (which is supposed to be independent of silt grade) and its indication that similarity can occur when $e = \sqrt{y}$.

Probably neither rule is *quite* correct.

9. In para. 6 it is shown that the distortion form $e = \sqrt{y}$ is consistent with constant run-off per unit area of two similar systems. In fact such constancy cannot exist but may be approximated to and this explains the case of "natural" distortion, erosion and accretion occurring until the natural balance is reached.

As to an artificial model the second rule of dynamic similarity, that resistance divided by gravity force, is the same for both systems, may be put quite simply if resistance is reduced to skin friction kv^2 per unit area.

$$kv^2/wrs = KV^2/wRS \qquad [w = \text{unit weight}]$$

and since, by the first condition of similarity, $v/V = 1\sqrt{y}$

$$\text{and } \frac{s}{S} = e\,; \frac{k}{K} = y\left(\frac{r}{R}\right).e$$

$$\text{or } e = \frac{k}{K}\left(\frac{R}{r}\right)\frac{1}{y}$$

For channels which are broad and shallow, i.e., with fairly small side slopes, *in the model*, $R/r = y$

$$\text{and } e = \frac{k}{K}$$

For channels which are deep and narrow (with steep side slopes) in the model, R/r is more than y [w, W = widths]

$$\left[\frac{R}{r} = \frac{A}{P}\frac{p}{a} = \frac{WD}{P}\frac{p}{wd} = \frac{W}{w}\frac{D}{d}\frac{p}{P} = \left(\frac{p/w}{P/W}\right)\frac{D}{d} = \left(\frac{p/w}{P/W}\right)y\right]$$

For a right angled triangle section of channel in the model

$$(p/w)\,/\,(P/W) = \sqrt{2}, \text{ nearly,}$$

so that in such case $e = \sqrt{2}.\,k/K$

and it can be more (say 2 k/K) for "very deep" channels in a model.

k/K as a function of r/R or vr /VR (Reynolds Numbers, with constant viscosity) varies from

$$1/\sqrt{r}/R = \sqrt{y} \text{ if } R/r = y$$

to much smaller values down to unity for strong "roller" eddying resistance so that

$$x\,v = e \backsim \sqrt{y}$$

down to unity for strong roller eddying such as occurs over weirs.

10. Opinions are frequently expressed by experimentalists that distortion should be less than such and such a value, but it seems clear that

(a) it *may* be as high as say $2\sqrt{y}$ for certain cases (e.g., if y = 225, e might be 30, if side slopes in the model were steep);

(b) a value of $\sqrt{y}$ is often applicable ;

(c) for strong roller eddying it should be unity. This condition, however, usually only applies to rigid obstacles and not to mobile beds.

(concluded at foot of next column)

The International Association of Navigation Congresses

Review of Papers Presented at the Lisbon Congress, 1949

(*continued from page 212*)

As mentioned in the Editorial columns of the October issue of this Journal, we intended to publish in this number, abridged versions of the General Reports on questions 1 and 2 of Section Two "Ocean Navigation." Unfortunately however, owing to limitations of space, we can only deal with question 1 in this issue, and question 2, dealing with Oil Handling, is unavoidably postponed until January.

SECTION II.—OCEAN NAVIGATION.

First Question.

Regularisation of natural and artificial estuaries including estuaries of small dimensions, tideless or otherwise.
Improvement of that part of the stream affected by the sea and tides. Recent observations and results. New methods.
Comparison of results obtained with those given by the tests on models or by calculation.

GENERAL REPORT BY H. SCHRECK
Director General of the Ports of Douro and Leixoês.

The problem of the improvement of the estuaries of natural and artificial waterways and of the estuaries, in the interest of navigation, is one of the most interesting and most complicated requiring the attention of those responsible for studying maritime works.

The problem is far from being completely resolved either in the laboratory or in nature; although an always greater knowledge of the meteorological, hydrographical, alluvial, hydrological and physiographical phenomena, general or local, and of their evolution, the development of new methods of calculation. the progress of the technique of the tests on models, the lesson of the favourable results and, sometimes the more instructive one of the failures, and on the other side the progress of dredging technique, with its corresponding lower cost, have to a great extent increased the possibilities of resolving it in an exact and economical way.

Improvement of the Estuaries

By improvement of the estuaries is to be understood the necessary arrangement to give the navigation, besides suitable nautical conditions, sufficient depth and width at an initial cost and at maintenance charges as low as possible.

To avoid deposits of sand and mud tending to diminish the depth of the channel in the estuaries, three ways, to be employed separately or together, are possible:

(a) to take advantage of the energy of the tide or of the waterway;
(b) to eliminate the causes of sanding up or of silting caused by river or by sea alluvium;
(c) to dredge.

The Distortion of Scales in Models with Loose Beds

(concluded from previous page)

(d) Values as high as 100 are not compatible with true similarity.

In regard to the last statement the practical success of certain models with such large distortions raises a question of such practical importance. Obviously in increasing rugosity in the model similarity may be approached even with distortion exceeding $\sqrt{y}$ but the latter already presupposes a much greater bed resistance in the model (per unit area and unit speed) than in the prototype, and there is a limit at which such distortion is improper. Except in so far as roller eddies disturb eddies with vertical axes the distribution of flow *in plan* may be acceptable in a model with large distortion, but the flow in profile must tend to deviate a great deal from that of the prototype. Another aspect of the matter is the development of scour in the model. As the resistance in the much distorted model tends to be deficient it may be that the excess of kinetic energy can be absorbed by scour, but it is a matter of experiment and not logic to demonstrate that the results are conformable to the behaviour of the prototype.

(a) In the case of estuaries or lagoons subject to tide, flux and reflux currents are powerful auxiliaries for maintaining the stability in plan and profile of the channel of the estuary. In some of the cases dealt with at the present Congress, no other means were used (Lisbon); in other cases the channel, after the initial dredging, has to be maintained by annual dredging on a small scale (estuary of the Thames).

Increasing the energy of the tidal waves means, in the case of a lagoon, to increase its storage capacity, acting on the surface, in depth and in amplitude, and to reduce to a minimum the losses resulting from the meeting of currents, whirls, etc.; and in the case of an estuary, to increase, in the same way, the storage capacity by rectifying the part of the stream affected by the sea and tides, in plan and transversal and longitudinal profile, to obtain a maximum range of tide over the maximum of the course, to reduce in the estuary all the losses of energy which may result from deviations in the direction of the current, islands, secondary branches, etc., and to direct the flux and especially the reflux in a straight or slightly bended line towards the direction of the outer tidal currents.

In the case of small estuaries, corresponding to small estuaries of waterways subject to swelling, it is useful to take advantage of the flood current to improve the depth of the estuary and of the navigable channel, with the limitations imposed by the necessity of avoiding floods at the estuary and infra-excavations in the structures of the entrance.

(b) The degradation of the estuaries may result from silting caused by the river or by the sea.

In the first case, be it a waterway discharging in to an estuary or a lagoon, the rectification of the waterway and of its tributaries, the reduction of its curves, the plant revetment of its banks, etc., may constitute the solution required. If not feasible and the energy of the tide is not sufficient for expulsion of the deposits, or if the importance of the traffic does not justify the permanent removal by dredging, deviation of the course of the waterway can be an advantageous solution.

In the second case, we are in the presence of complex phenomena, the evolution of which has to be carefully studied for each site. The knowledge of the meteorological characteristics, of the direction and amplitude of the waves and of the coastal currents, of the nature of the bottoms, of the bathymetry, of the origin of the alluvium, the analysis of the hydrographical evolution of the estuary from the earliest possible date, of the effect of works executed, if any, and the comparison with similar cases elsewhere, give a preliminary idea on the drift and the intensity of the alluvium.

Closely related to the phenomenon of the drifting of alluvium along the coast is the formation of bars in the estuaries. Actually it is possible in certain cases, by properly isolating the intervention of the agents of these phenomena, to know, à priori, the conformation given to the littoral by each one of them. One knows, for instance, that waves of a certain length and amplitude, acting normally on a shore, the initial profile and the constituting material of which are known, produce after a certain time a new profile known by the formation of a bank the depth of which and the distance of the border can be defined. One also knows that, if the incidence is oblique, the longitudinal drifting of the material of the shore intervenes and that the intensity of this drifting varies also to a certain point with the new parameter, the angle of incidence. A great step forward has been made in the knowledge of the propagation of the waves in relation with the bathymetrical shapes and natural or artificial accidents of the coast, the new and most interesting method has loomed up to determine the currents which occur as a consequence of the raising of the main level, between the zones beaten by the waves and those which are most protected.

But as the law of variation of the agents of the alluvium drifting can not be foreseen, and on the other hand the resultant of the simultaneous inter-action is not known, solving of the problem can actually not be obtained from calculations and, in each instance, enlightenment is sought by having recourse to models.

It is possible, however, to set forth certain rules, with no absolute character, but rather subject to careful verification in each case, to model the first scheme to be adopted in view of protecting the estuary against siltings.

International Association of Navigation Congresses—continued

As a rule, alluvium drifts along the beaches, chiefly in one direction, in quantities which are at their maximum in the foreshore zone and diminish with the depth.

If a mouth opens on to a beach, the solid current of alluvium causes it in time to migrate in the direction of the drift. A method for avoiding, consists in fixing its banks on the side least exposed to the wind; but to improve the depths, especially when a small estuary is involved, it is necessary to protect it on the side which is most exposed to the wind, by building a jetty intercepting the alluvium drifting along the shore.

This work causes accumulation of materials and a tendency of the bathymetrics to keep clear the shore by forming a tangency with its extremity, thus causing, in the alternation generally observed of the causes of alluvium drift, the silting up of the estuary through materials carried from the opposite direction.

Hence the necessity to develop simultaneously two jetties across the zone where the drifting is most intense. At the point of the jetties invariably a bar will form, by which the alluvium will get to move again, though initially, with less intensity. A powerful waterway or the reflux of great hydraulic force may, when their current is properly directed, eventually by semi-submerged dikes, dispense with the defence works of the estuary, but the bar will form all the same. From neither of these processes the disappearance of the bar can be expected, alone the fixing of it, its keeping clear of the estuary and an important contribution of the so directed ebb current to the preservation of the depths of the channel that runs through it.

With regard to the small estuaries frequented by small draught vessels, they should be amply protected by jetties, without disdaining the help of the flow or ebb current, as the cost of works in this case generally is low (less extension and less depth) and maintenance-dredging, difficult to execute owing to lack of manœuvring space, may represent a permanent cost, the importance of the port does not justify.

In large estuaries it is advisable to exhaust the possibilities of preserving the required depth by using the energy of the ebb, properly directed, and by dredging, as building works generally entail too great an expense.

(c) Dredging, as a rule, is the most effective means to use for improving the estuaries and for opening and maintaining the channels of the bar. Successively greater depths required for the navigation can, in many cases, be obtained in the estuaries and in the mouths by taking advantage of the energy of the tidal currents, but at the bars, as a general rule, dredging alone can do it. It may be stated that dredging can be reduced to a minimum by orienting the channel, in a straight or slightly curved line, in a direction near as possible to that of the tidal currents and of the dominating seas.

An interesting example of estuary improvement by dredging is that of the channel of the Thames as shown in the paper of Mr. Shankland. The estuary of the Thames is well calibrated and there is, properly speaking, no bar at its exit; the natural depths of the estuary were, however, not sufficient and the channel used for navigation purposes was not stable. A sound and complete study of all the elements of the problem made it possible to cut a new channel through the sand and mud deposits of the estuary (Yantlet Channel), which is so favourably oriented that since its opening its depths have increased in a natural way.

The paper of Mr. Leighton refers to the case of the Mersey. Similarly to the Thames, the fresh water current at the estuary is very small in comparison with the currents of the tide, but in this case there is a bar. Up to the time when dredging was started (1870), the depths at the bar were very small (10 to 12 feet), and the navigation channel between the bar and the mouth was unstable.

Dredging has made it possible to increase the energy of the tide, to maintain, with reasonable annual preservation work, a depth from 28 to 30 feet at the bar and a wide and deep channel. The curvature of the channel (in plan) initially adopted to take advantage of the natural bottoms, tended however to widen, and in 1909 the degradation was already difficult to rectify by dredging.

The study of the problem, completed by tests on small scale models, showed that the curved channel, preferable for reasons of economy, could be maintained perfectly by reducing its curvature and the construction of training walls. This work, interrupted during the war, is actually being finished and seems to confirm perfectly the conclusions of the study, considering the dredging economy that has resulted from it.

Mr. Gibert's paper constitutes a most valuable contribution to the enlightenment of the problem. It explains the regime of the French maritime rivers Seine, Loire, Gironde and Adour and the improvements carried out in the mouths, estuaries and parts affected by the sea and tides.

While regretting to have to summarise such interesting work that should not be abridged, we extract from it the following main considerations:

In the French Atlantic rivers the great natural power, to utilise for improving their entries and estuaries, is the tide.

Its utilisation depends on the special conditions in each case, which therefore should be known thoroughly.

The improvement of mouths and that of the part of river affected by the tides cannot be dealt with separately. As generally in that part exist the greatest limitations to their regularisation, it is there that the study should start.

Classical rules can be applied for the correction in plan and profile, without losing sight of the fact that dredging now dispenses with the necessity to contract too much the course which would be a hindrance to the propagation of the tide and consequently to the navigability and the preservation of the channels of the estuary and of the mouth. Means at hand are dikes, groynes and dredging.

At the joining of the part affected by tides and the estuary, classical rules should be turned down, as there the effect of the banks is progressively getting smaller and there is the danger of reducing the energy of the tidal wave. This zone should be studied on a model.

The navigation channel in the estuary must enable a proper superposition of the flow and ebb currents, or at least the concentration of the ebb.

The channel of the bar must, without great deviations, receive the ebb current and have an orientation as near as possible to the direction of the flow and waves.

In large estuaries, building of dikes, not only in the estuary but chiefly on the bar, is too expensive and does not lend itself to the solution of the problem by approximations.

Dredging is the best means and must as a rule be applied quickly and vigorously to get full results.

The regularisation of small mouths in seas with a small tidal range is dealt with in the paper by Messrs. Greco Buongiorno and Ferro, together with the improvement of the mouths in the lagoon of Venice. The verification of the utilisation of the tide (although weak) for maintaining the depths in the small mouths, with the aid of tidal basins and a network of canals, is most instructive.

Mr. Valderrama's paper is a study of the regularisation of two small mouths on the Spanish N.W. coast; to improve one of these mouths it is planned to create a scouring current and, for the other to rectify a bend of the estuary and to canalise the ebb-tide current in the zone of the bar.

Mr. Abecasis, in his paper, draws attention to the general and local characteristics of the river mouths and lagoons of the Portuguese coast and, with the knowledge resulting from many years of observation, the study and carrying out of maritime works in nearly all its ports; he concludes that on coasts with important alluvial drift:

1—Which are very exposed:

(a) without works protecting the mouth, the preservation through dredging is difficult unless a powerful estuary is involved.

(b) with outer works, the preservation through dredging is moderate.

2—Which are moderately exposed:

(a) without works the preservation by dredging is possible, except when the mouth is situated at a point of the coast with constant alluvial increase.

International Association of Navigation Congresses—continued

(b) with outer works, the preservation by means of reduced dredging is possible if the layout of the works is inspired by knowledge of the hydrographic evolution of the mouth, and by harmonising the conditions with regard to the alluvial drift with the direction of the flux and reflux currents.

If these conditionings do not agree, one has to consider the second dominant, with the idea of directing the extremity of the channel towards the reflux current, which measure is generally favourable also with regard to the flux current.

Improvement of that part of the river affected by the tides

This question cannot be separated from the previous one, as the improvement of the part affected by the sea and tides has its repercussion on that of the mouth and inversely.

The leading rule for this study is, as shown in previous Congresses, a maximum utilisation of the river and tidal energy in order to maintain, with a minimum of dredging, the depths required for the traffic and which are generally greater than those the river would cut in its natural bed. In this respect, the paper of MM. Gibert and Durepaire on the French Atlantic rivers is of the highest interest.

Comparison of results obtained with those given by tests on models or by calculation

The test on models enables the simultaneous study of the action of all or nearly all the agents intervening in the moulding of the waterways, estuaries and bars. It is therefore more and more used, not only for explaining the phenomena actually observed, but also for determining the degree of improvement that can be reached by new works and dredging.

The paper of Mr. Oscar Elsden gives an excellent summary of the tests on models made in England for the study of the estuaries subject to tides. While making the reservation that for some cases it is still necessary to consult nature for the confirmation of the results obtained in models, he concludes that:

. . . it is possible to find in models the correct reproduction of the tidal wave, its velocity of propagation, the geometrical locuses of the low and high tides, and providing there exist no sudden irregularities in the depth and width of the channels, even the velocity of the currents produced by the tidal wave;

. . . the bed of properly selected mobile material of the model submitted to the natural actions, reduced to scale, of the river and tidal current takes after a certain time the shapes of nature, reproducing the longitudinal and transversal profile, the depth of the channels and the height of the bars. One does not obtain a perfect reproduction of the banks because of the necessary distortion of the model. On the other hand, the formation of ripples renders a detailed verification of the bathymetric similitude rather difficult so that the slopes appear less developed and the channels less deep than in reality but, considering the volume of materials deposited in a space of a certain size, it seems that interesting qualitative data can be drawn from models.

. . . the reproduction of the phenomenon of sedimentation of river mud in contact with sea water, although difficult, owing to the fact that the horizontal velocity of transport and the vertical velocity of sedimentation obey the same linear distortion of the model, is nevertheless possible by adding to the sea water of the model a coagulant capable of properly accelerating the precipitation. The tests which were carried out have given results near to reality.

. . . It is possible to reproduce quite exactly the effect of floods on the tidal wave, and also the effect of wind on the formation of waves and the corresponding drift of material along the coast.

The paper of Mr. Thompson, director of the U.S. Waterways Experiment Station, deals with three typical cases of improvement which verified the model tests.

The first case concerns the improvement of the direction of the tidal current in the East River, near New York, where tortuous alignments of the banks, together with a great velocity of the current, make navigation difficult. It was a relatively simple problem of hydraulic flow easily resolved by tests.

The second case is the one of the delta of the Mississipi. The river has a sufficiently abundant discharge of head waters to justify the fact that one has tried from the beginning to take advantage of the current, by concentrating it between successively confining dikes and by graduating the distribution of the waters in the branches of the delta, in order to maintain the depths in the branches and their bars used for navigation. Attention is drawn to the fact that, having verified the existence of a strong E.W. coastal current, it was possible, by orienting the channel of the bar of the South Pass in the direction of this current, to maintain its depth without excessive work. Notwithstanding successive contractions and extensions of the jetties, the depths of the South-west Pass are, however, not considered to be sufficient and it is hoped that study of a model will show the way to realise proper depths without the use of important dredging.

The third case is similar to the general case of an estuary subject to the tides with formation of an extensive bar and a longitudinal drift of material. The migration of the channel of the bar in the direction of this drift made the navigable channel very winding and difficult between the bank and the coast. A study on model was made of the dredging of a new cut across the bank. The tests have shown that the best lay-out would not dispense with maintenance dredging. This was confirmed by experience.

The paper of MM. Léon Bonnet and J. Lamoen shows a case of local improvement of the Scheldt for the purpose of correcting the direction of the flux in a bend of the river, near the piers of a bridge to be reconstructed, without causing damage to the existing depths.

The case was dealt with on model in the laboratory at Antwerp. The adjustment of the model was done by graduating the various parameters so as to obtain the reproduction of the natural bathymetric upsweep and of the trajectory of the current. To this effect, the deformation of the scale of the velocities was increased to produce a greater transport of bed-materials. The natural ratio of flux and reflux velocities was, however, maintained. The model has shown that the solution consisted, due to the ebb tide, in modifying the river bank. After the works were carried out, the indications of the test were completely confirmed.

The paper of MM. J. J. Dronkers and J. Van Veen is a valuable work, disclosing the calculation methods developed in Holland to establish the propagation of the tide in a river or in a network of branches affected by tides. It is certainly the only case where calculation supplied a means of solving one of the fundamental problems of the question.

The predetermination of the tide levels in the Waddenzee, as a result of the closing of the Zuiderzee, was supplied by Lorentz.

Mr. Mazure has developed the Lorentz method for the case of sea rivers, taking into account the existence of the flood-tide current.

Mr. Dronkers has established a new method, more complete and rigorous, for calculating the propagation of the tide in sea rivers or arms. Mr. Van Veen presents a curious electric model for calculating tides by taking advantage of the analogy between the currents and the water levels and the intensities and the tension of the electric current.

Conclusions

1.—A plan for the improvement of an estuary should be preceded by the study, as complete as possible, of all the factors that can intervene in its modification, of the analysis of its hydrographical evolution, and of the experiments that will show which way these factors react to the attempts of improvement; the experiments which are most generally indicated are, on a natural scale, the dredging tests and, on the laboratory scale, the model tests.

2.—The following rules, generally speaking, may be given for the improvement of the mouths and in the most complicated cases, for fixing, as a first approximation, the scheme to be submitted to the tests.

(a) **Regularisation of the mouth and bar by taking advantage of a permanent fluvial current and of temporary flood currents.**
—Works for concentrating the current and defending the mouth against the littoral alluvial drifts, consisting of

International Association of Navigation Congresses—continued

parallel jetties extending to the bar, oriented in the direction approaching the one of the predominant littoral current.

—Eventual use of dredging.

—Applicable to an estuary in tideless seas, to deltas and to small mouths of tidal estuaries with a reduced storage capacity.

(b) **Improvement of the mouth and of the bar, mainly by making use of the tidal currents.**

—To establish in the estuary by dredging up to the neighbourhood of the bar, an open main channel, protected, if absolutely necessary by dikes widely cambered with a minimum projection from the bottom, enabling the superposition of the flux and reflux tides or, at least, the concentration of the latter, conform to the direction of the course taken by the sea and tides, to the flood-tide current and to the direction of the channel of the bar.

—To dredge in the bar a cut as straight as possible and well in keeping with the channel of the estuary and having as much as possible the direction of the outer flood and ebb-tide currents, and especialiy of the latter and the direction of the dominating seas.

—When necessary and economically possible, to build works to defend the mouth against littoral alluvial driftage. In small and medium mouths which are sufficiently exposed and on a coast with heavy alluvial drift, the system of two convergent jetties, so disposed that they form a slight obstacle to the continuity of alluvial flux, is generally advisable; in small mouths which are little exposed, parallel jetties combined with the action of natural artificial scouring may be found rather suitable.

—Applicable to mouths of estuaries or lagoons affected by tides.

3.—The improvement of the part of the stream affected by sea and tides, with the double object of improving the navigability of the river and preserving the mouth, must yield to the necessity for facilitating propagation of the flood-tide current, of increasing the range of tide and of utilising the energy of the ebb-tide current to maintain depths in a natural way. For the lay-out, a prudent use has to be made of the effect of the bank, taking into account the dissipation of energy which results from it, and the fact that a too narrow course, although in keeping with the actual calibration of the mouth, does not leave a margin for future improvements.

For comparative verification of the project, calculation and model tests will have to be used; for its carrying out, dikes, groynes and dredging are the means at hand.

New American Hopper Dredger

Designed to Operate in New York Harbour

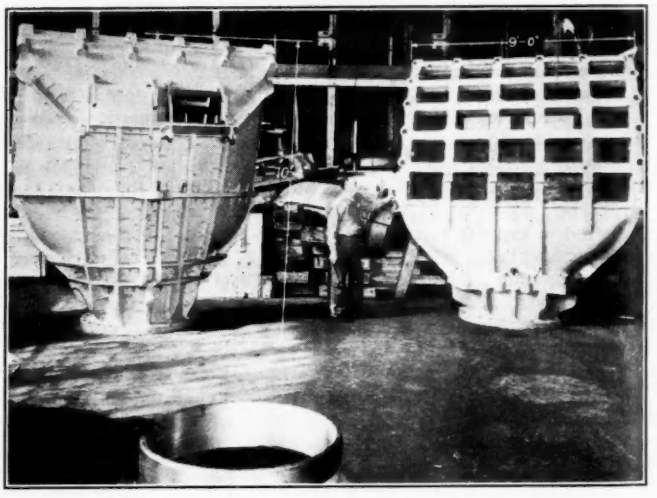
The world's largest seagoing hopper dredger, the *Essayons*, built for the Corps of Engineers at a cost of $10,000,000, was launched successfully on August 25 last at the Sun Shipbuilding and Dry Dock Company yards in Chester, Pa.

Designed to operate in New York Harbour, this dredge features a trunnion connection in the suction pipes which permits them to be hoisted clear of the water, an "unwatering system" that removes water locked in the bins after dumping, a gas ejection system that increases pumping efficiency, twin screws and twin rudders to increase maneuverability, and all types of safe navigation devices. The pilot house is forward, hopper space and pump room amidship, and the boilers, turbo-generators, and propulsion motors aft. The hopper space is divided into four hoppers by transverse bulkheads. Each hopper is then sub-divided into three bins athwart ship by longitudinal bulkheads, and each bin is fitted with two bin gates at the bottom of the vessel.

The overall length of the *Essayons* is 525ft. 2in., length between perpendiculars 500ft., beam moulded 72ft., depth moulded 40ft. 5in., draft loaded 27ft. 8in., displacement tonnage loaded 22,120, and hopper capacity 8,000 cubic yards. The power plant, capable of delivering 8,000 shaft horsepower, will propel the ship while dredging at a 3 m.p.h. rate against a 5 m.p.h. current. The estimated vessel speed, fully loaded, in shoal water, is 15.5 m.p.h. The main power plant is of the turbo-electric type equipped for automatic operation throughout. Steam is supplied by two sectional header marine water tube boilers, oil fired and designed for 600 pounds per square inch working pressure at 850 degrees Fahrenheit total temperature. The boilers are equipped with superheaters, de-superheaters, tubular air heaters, automatic superheat control, automatic feedwater control, automatic soot blowers, and automatic combustion control. Each boiler has a normal evaporation rating of 60,000 pounds of steam per hour and an overload rating of 75,000 pounds per hour.

Power for normal operation of the ship is provided by two geared main turbine-generator sets each equipped with constant speed governor, overspeed trip and a trip which automatically closes the steam supply in the event of failure of the lubricating oil pressure. These turbines are conventional marine type operating normally at about 5,400 r.p.m. Each turbine drives, through a single reduction gear, three generators connected in tandem. The normal capacity of each turbine is sufficient to produce 4,000 horsepower propulsion on one shaft and develop 500 KW for auxiliary power. The generators driven by each turbine are for auxiliaries, pumping and propulsion.

The propulsion motors are installed directly below the generators and speed is obtained by variation of the propulsion generator voltage. Each motor is fitted with a tachometer generator



Drag heads which are assembled on the suction pipes of the *Essayons*.

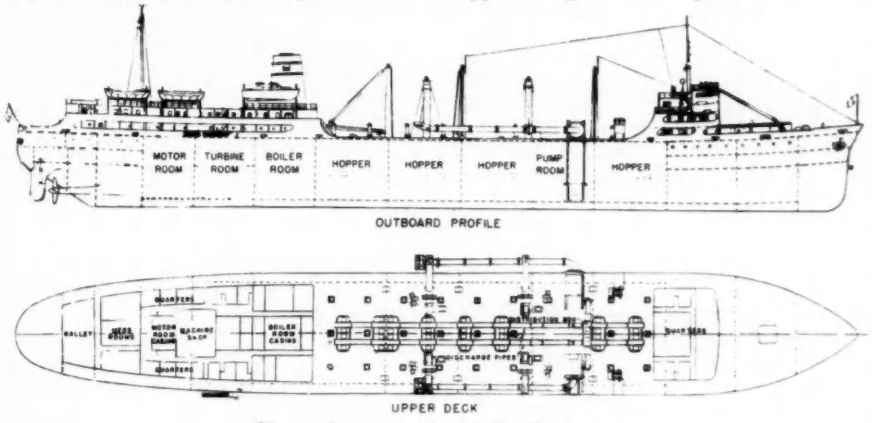
which is connected to indicators located in the engine room and in the pilot house. Up to full speed in either direction, the propulsion speed can be controlled from the pilot house or from the engine room. After full speed has been reached, full power is maintained on each propellor by an automatic regulating unit.

Dredging is performed by two pumps located port and starboard in the pump room. These pumps are of the centrifugal side-suction dredge type, having 36in. diameter suction and 32in. diameter discharge. The casing and impeller are alloy cast steel. The head liners are alloy cast iron and the shoulder and throat liners are moulded rubber with steel inserts. Each pump has a theoretical capacity of 63,450 gallons of water per minute at a speed of 180 r.p.m. The pumps discharge into a central distribution box located on the upper deck above the pump room.

The two 36in. suction lines are suspended along the outside of the ship, one port and one starboard. A rubber surfaced ball and

New American Hopper Dredger—continued

socket type universal joint is installed in each pipe about 30 feet from the trunnion to provide flexibility. The draghead designed to maintain contact with the channel bottom and to act as an agitator and strainer for the material to be dredged, is installed on the lower end of the suction pipe. The suction pipe is supported at the ball joint and at the draghead by cables connected to motor-driven winches on deck. The depth to which the drag can be lowered is controlled by manipulation of the winches. Gauges are installed to indicate the dredging depth at all times. The suction head or drag can be lowered to a depth of 62 feet at an angle of about 45 degrees, which is the maximum dredging depth. The vessel will be equipped with the largest adjustable type dragheads ever installed on a hopper dredge. This type of draghead was developed by Mr. F. C. Scheffauer, Consultant, formerly of the San Francisco District, Corps of Engineers, and is in general use on hopper dredges.



Plan and cross section of the *Essayons*.

An unusual feature of this dredger is a sliding trunnion connection which permits the trunnion and drag pipe to be hoisted above the water when the vessel is not engaged in dredging. This feature removes a major appendage from each side of the hull, will result in increased vessel speed and provide for greater safety while navigating to and from the disposal area. In addition provision has been made to breast-in and stow in saddles on deck the entire drag pipe when required for a sea voyage, docking or maintenance.

Another important feature is the gas ejection system developed by Mr. R. H. Hoffman, of the New York District of the Army Engineers. In recent years a large increase in the amount of gases, principally marsh gas, contained in the bottom material in many areas has detracted seriously from the efficiency of dredging operations. At the river bottom, this gas is retained under pressure in the material, and as the dredging process releases it the gas enters the pump in greatly increased volume, so that the pump loses suction. A number of experiments with ejectors of several types have been conducted and the most effective has been installed on the *Essayons*. It consists of a liquid piston vacuum pump capable of 1290 c.f.m. at 20in. vacuum whose suction end is connected to the dredge suction pipe at a point near the dredge pump. The suction pipe casting at this point is a separation chamber. The extraction point for the vacuum pump is at the top of this chamber. The released gas is then drawn off by the vacuum pump and discharged to the atmosphere.

An unwatering system is installed to remove water remaining in the bins when the gates are closed after dumping has been completed. Thus, when dredging is resumed, dilution of the dredged material being pumped into the bins is avoided, and a greater percentage of solid material in the bins is obtained. The "unwatering system" consists principally of a 7000 g.p.m. centrifugal pump driven by a 125 h.p. motor located in the dredge pump space, 10in. suction pipe branches connected to each bin, and air-operated main and selector valves in all main, branch, and backwash piping.

The electrical equipment features three generators on the port side and three identical generators on the starboard side, each set mounted in tandem and geared to the main turbine on that side of the ship. All generators are D.C. and each set contains a dredge pump, propulsion, and auxiliary generator. The propulsion generators deliver 3,300 kilowatts each and are shunt wound for 600 to 720 volts. Potentials of this order are used to keep the generators and motors of large capacity within reasonable dimensions. Higher potentials have been avoided because of possible dielectric difficulties in the humid atmospheres common to dredging practice. The dredge pump generators are each rated at 1600 kilowatts and are shunt wound for 600 volts. The auxiliary generators are each rated at 500 kilowatts and are "three-wire" machines shunt wound for 120 and 240 volts. Propulsion and dredge-pump generators are enclosed in housings which contain a blower, cooling coils and air filters so that dust is removed from the circulating air and favourable temperature conditions are maintained during operation.

There are two shunt wound propulsion motors, each rated 4,000 horse-power at 92 to 110 r.p.m. and connected directly to a propeller shaft. The dredge pump motors are shunt wound and rated at 1,850 horse-power each on application of 500 volts at a speed of 155 to 180 r.p.m.

Modern navigation devices include an electric draft indicator which shows at all times the fore and aft draft of the ship; a recording, precision depth finder which provides a permanent record of channel depths before and after dredging; a gyro-compass with repeater stations, a binnacle-type radio direction finder; and radar.

This dredge will require a crew of 133 officers and men to operate it seven days a week. A well-equipped laundry will be furnished for the convenience of the crew. Recreation rooms will be equipped with card tables, tennis tables, book and magazine racks and facilities for motion pictures and safety meetings. A well-stocked ship's store will be provided. For additional crew comfort, all quarters, dining and recreation spaces will be heated and ventilated in cold weather and cooled, dehumidified and ventilated in hot weather. During hot and humid summer days the temperature in all living spaces will be kept down to 80 degrees dry bulb at approximately 67 degrees wet bulb.

The *Essayons* was designed by the Marine Division of the Philadelphia Office of the Army Engineers under the direction of Colonel F. F. Frech, District Engineer, and supervision of Mr. W. H. Roberts, Chief of the Marine Division. The keel was laid down on 15 December, 1947, and construction is under the direction of Mr. R. L. Burke, Vice-President and General Manager of Sun Shipbuilding and Dry Dock Company.

Increased Trade at Humber Ports

There was an increase of 1,625,251 tons representing 15 per cent. in the total volume of inward and outward traffic through the Humber Ports during the 44 weeks ended 6th November, 1949, compared with the corresponding period of 1948. The respective figures were:

1949 12,403,169 tons 1948 10,778,918 tons.

Coal and coke shipments were heavier by 1,105,494 tons and there were also larger inward tonnages of mineral oil, iron and steel and timber. Grain, flour and milling offals however, showed decreases. Outward tonnages of iron and steel manufactures and mineral oil were higher, but grain and milling offals did not reach the 1948 tonnages.

The number and N.R.T. of vessels entering exceeded the 1948 figures by 323 and 736,794 respectively, the figures being:

1949 8,349 vessels, N.R.T. 6,946,360
1948 8,026 vessels, N.R.T. 6,209,566

The National Association of Inland Waterway Carriers

Excerpts from Sixteenth Annual Report of the Executive Committee

The Annual General Meeting of the National Association of Inland Waterway Carriers was held in Leeds on the 10th November last, and the following extracts from the Annual Report for the year ended 30th September, 1949, are likely to be of interest.

Membership

During the year the following new members and associate members joined the Association:—

Members:—John Knill, London; and James Monk & Sons, Adlington, Lancs.

Associate Members:—The Anglo-American Oil Co., Ltd., London; Richd. Hodgson & Sons, Ltd., Beverley, Yorks; and Wheatcraft, Ltd., Gloucester.

The following associate members withdrew from membership:—G. T. Beevers, Goole; and F. Brigham, Goole. At September 30, 1949, therefore, the membership constituted 57 members and 29 associate members, representing 1,763 craft of a carrying capacity of 108,896 tons.

Co-operation with Nationalised Transport

Under the Transport Act, 1947, all the principal railways, as well as the inland waterways of the country (with one exception) vested in the British Transport Commission on January 1st, 1948, and since then a considerable number of major road haulage concerns have likewise become nationalised, and in this respect the process is continuing. In comparison, apart from the few carrying undertakings who have been taken over by the Docks & Inland Waterways Executive, the carrying side of the industry remains in independent hands.

It became very evident as events arising from the Transport Act were unfolded, that the Association and its members could not hope to achieve anything by adopting an attitude of isolation but, on the other hand, much could be gained by offering to co-operate with the nationalised bodies.

The executive committee feels that the progress which has been made in this direction during the past twelve months will be endorsed by the members.

Co-operation with the Docks & Inland Waterways Executive

Tolls and Charges.—In the periodic exchange of views between representatives of the Association and the Docks & Inland Waterways Executive the unenviable position of independent canal carriers, particularly narrow boat owners, competing with nationalised and to no little extent subsidised transport, has been stressed, but high policy apparently dictates that the status quo in regard to the existing level of rates should as long as possible remain as at present. The hoped for increase in rail rates seems to be no nearer reality.

The Docks & Inland Waterways Executive are, however, sympathetic and at the last discussion promised to consider any cases of hardship concerning tolls and charges in which they are interested.

There is apparently no prospect of a revised schedule of tolls until a new rates structure is established.

Co-ordination of Tolls.—Some progress has been made by the Docks & Inland Waterways Executive in the co-ordination of tolls on through traffic, and Divisional Waterways officers are giving further attention to this matter. Carriers wishing to have the benefit of a single toll charge on through traffic should make the necessary representations.

The institution of service charges by the National Coal Board from May, 1949, onwards, for loading coal to water route, the charges for which vary from one area to another, has been the subject of strong representations by the Association in conjunction with the Docks & Inland Waterways Executive.

Although some modifications of the new charges have been conceded, the Association continues to press at local and national level for further alleviation of the position.

Wage Negotiation Machinery

The reconstituted National and District Joint Councils for the Inland Waterway Industry are now functioning smoothly, the Employers' side consisting of representatives of the Docks & Inland Waterways Executive and of independent carriers.

Inland Waterways Association

It cannot have escaped notice that the Inland Waterways Association has been publicising the inland waterways of the country, and our members will be interested to know that renewed discussions have taken place between officers of that body and this Association.

International Association of Navigation Congresses

The 1949 Congress of the International Association was held in Lisbon during September, 1949, and Mr. G. L. Lyon of Messrs. John Harker, Ltd., and associated companies, kindly offered to represent the Association.

Mr. Lyon brought back an interesting account of the proceedings and members wishing to have further information are advised to read the review of papers presented at the Congress appearing in the October, 1949, and following, issues of "The Dock & Harbour Authority".

Education Act, 1944

In February, 1949, it was reported that the Birmingham Education Authority had made progress with a view to the purchase of premises at Erdington for the setting up of a boat-children's hostel.

Later, discussions took place in the Potteries area with Health and Education officials on the same subject.

The carriers have offered to co-operate in all measures designed for the welfare of the boat-children, but as yet it does not appear that either in Birmingham or the Potteries district have the authorities reached conclusions in the matter.

Canal Abandonments

The British Transport Commission Bill for abandonment of sections of the Swansea Canal and the Monmouthshire Canal, also the section of the River Aire between Thwaite Dam and a point near Fishpond Lock, Rothwell, was considered, but there was apparently no case for opposition.

For the same reason, the proposal to abandon the Barnsley Canal and the major portion of the Rochdale Canal for traffic purposes was also unopposed. The Bill relating to the latter navigation was withdrawn.

Re-election of Officials

The following officers were re-elected for the ensuing year:—President: Mr. Norman N. Bird, M.B.E., F.I.C.S., M.Inst.T. Chairman: Mr. J. O. Wood, O.B.E., M.Inst.T. Secretary: Mr. A. Hayman.

British-Made Radar.

The Ministry of Transport stated recently that at present British ships are being fitted with commercial radar sets at the rate of about 15 a month, and to date nearly 400 British ships have been equipped. In addition, over 200 foreign ships are now equipped with British-made radar. Eight types of radar set, shared between four British manufacturers, have so far received the certificate of type-testing from the Admiralty Signal and Radar Establishment. Admiralty scientists are also pursuing on behalf of the Ministry many promising lines of research, including experiments with beacons for use with radar which, if satisfactory, should simplify identification of important navigational marks. In order to promote further the sale of British radar, the Central Office of Information have produced, for showing to buyers overseas, a 25-minute film called "In all Weathers," which tells the story of the development and use of radar for merchant shipping.

Severe Fire at Liverpool Docks

We regret to announce that severe damage was caused by a fire, which occurred early last month, at the Port of Liverpool. As soon as the outbreak was discovered, fire brigades were summoned from all parts of south-west Lancashire and Cheshire; they were reinforced by the fire-fighting train from Horwich, Lancs., by equipment brought 40 miles from North Wales, and by the fire-boat "William Gregson" and the rescue tender "Salvor". In all, 250 firemen were involved, but in spite of all their efforts, they were unable to control the blaze and could only concentrate on preventing it spreading to other parts of the port.

The shed concerned was the South Shed of Gladstone No. 2 Branch, which is a treble storey building about 1,250-ft. long and 100-ft. wide, divided into four sections. The fire broke out on the top floor of the 2nd Section from the west end, which was used as a warehouse and contained a large quantity of rubber and other commodities, as did the top floors of the remaining sections. The ground and 1st floors were, in general, full of cargo awaiting export.

The fire spread with great rapidity and ultimately involved practically the whole of the three Eastern sections, the West section, owing to the direction of the wind and the efforts of the fire brigade, escaped damage by fire, although a certain amount of damage was caused by water and molten rubber.

The roof of the three Eastern Sections subsequently collapsed, carrying with it 13 roof cranes, eight of which fell into the dock.

As was to be expected, the rubber stored in the affected sections melted, and ultimately the whole of the avenue between the two branch docks and a very large area of the East roadway across the end of the dock was covered with a mixture of rubber and water.

Until it is possible to carry out complete examination, it is difficult to assess the full extent of the damage, but preliminary surveys indicate that the ground floor, apart from superficial damage to the concrete work and the loss of a number of doors, will be re-usable. It is also anticipated that a considerable amount of the 1st floor will, likewise, be able to be restored, although there are areas of the 2nd floor which, forming as they did the covering of the 1st floor, are rather badly damaged and will have to be cut out and rebuilt.

Up to the present there is no information regarding the cause of the outbreak and enquiries are continuing.

River Danube Commission

Non-Recognition by Western Powers

It was recently announced in Washington that the United States, Britain and France, in formal notes to Russia, Yugoslavia, Czechoslovakia, Bulgaria, Hungary and Rumania, have intimated that they do not recognise the new Soviet-sponsored Danube River Commission. The notes pointed out that the Commission had violated the Balkan peace treaties, ignored 130-year-old shipping rights, and was "clearly designed to enable the Soviet Union to maintained a monopoly of commerce on the Danube." The notes also hinted that the Western Powers may take the Danube dispute before the United Nations as a violation of the treaties guaranteeing free navigation, and said the Western Powers would continue to operate and control that part of the Danube within their occupied zones, independently of the larger portion controlled by the Russians.

PUBLIC APPOINTMENT.

IPSWICH DOCK COMMISSION.—Applications are invited for the position of Secretary and Solicitor at a commencing salary of not less than £1,000 per annum. The person appointed would be required to devote the whole of his time to the work of the Commission and would not be permitted to engage in private practice. Applicants must not be over the age of 40. The successful applicant will be eligible to join the Commission's Pension Scheme, and a house can be provided at an economic rental. Replies should be addressed, not later than the 15th December, 1949, to The Manager & Clerk, Ipswich Dock Commission, Old Custom House, Ipswich.

PUBLIC APPOINTMENTS.

BOROUGH OF SCARBOROUGH.
APPOINTMENT OF HARBOUR MASTER.
(Revised Advertisement.)

This is a revised advertisement. Applicants who put in applications in accordance with the earlier advertisement for the same post need not apply, since their applications will be considered together with additional applications received under this advertisement.

Applications are invited from suitable candidates holding a Master's Certificate or having administrative experience of harbour management for the appointment of Harbour Master at the Port and Harbour of Scarborough, at a commencing salary of £595 rising to a maximum of £660 per annum on Grade VI of the National Scale of Salaries for Local Authorities. Applicants must not be more than 50 years of age and should preferably have general port traffic and dredging experience. Experience of tidal harbours and the work of a coastal master will be of advantage.

The successful candidate will be required to pass a medical examination and to contribute to the Corporation's Superannuation Fund. The appointment will be subject to one calendar month's notice in writing on either side at any time.

Candidates should submit applications, stating age, experience and qualifications, and give the names of not more than two persons to whom reference may be made. Applications should reach the undersigned by 28th December, 1949.

Canvassing, directly or indirectly, will disqualify a candidate.

E. L. HORSFALL TURNER.
Town Clerk.

Town Hall,
Scarborough.
1st December, 1949.

TYNE IMPROVEMENT COMMISSION.

The Tyne Improvement Commissioners invite applications from qualified persons for the position of Senior Assistant Engineer under their Chief Engineer, Mr. R. B. Porter, M.I.C.E.

Applicants must be Chartered Civil Engineers with extensive experience in the design and maintenance of dock and harbour works and installations. The person appointed will be responsible to the Chief Engineer for the preparation of designs, estimates and contract specifications and drawings in connection with new works schemes, etc. Mechanical experience is desirable though not essential.

Salary—£700 per annum rising by annual increments of £25 to £800 per annum, plus War Bonus (at present £65 per annum).

The person appointed will be subject to the provisions of the Commissioners' Superannuation Scheme.

Applicants must not be less than 32 years of age nor more than 45 years of age on the 1st January, 1950.

The person appointed will be required to reside in the district and devote himself exclusively to the service of the Commissioners.

Applications on a prescribed form, copies of which may be obtained from the undersigned, will be received up to the 12th January, 1950, and should be addressed to the Secretary in an envelope endorsed "Senior Assistant Engineer".

Canvassing will be a disqualification.

By Order,
J. K. McKENDRICK.
Secretary.

Tyne Improvement Commission Offices,
Bewick Street,
Newcastle-upon-Tyne, 1.
25th November, 1949.

IMPROVEMENTS SCHEME AT FENIT PIER.
RESIDENT ENGINEER.

Applications are invited by the Tralee and Fenit Pier and Harbour Commissioners for the position of whole time temporary Resident Engineer to supervise the carrying out of the Improvements Scheme to Fenit Pier.

Applicants must have at least four years' experience in either the construction or supervision of harbour works, including reinforced concrete jetties, and must have a Degree in Engineering or its equivalent.

The period allowed for the execution of the works is 30 months.

The salary will be at the rate of £13 13s. 0d. per week. The appointment may be terminated on the receipt of 14 days' notice by either party.

Candidates may be asked to attend at the office of the Consulting Engineers, Messrs. P. H. McCarthy & Son, 26, Lower Leeson Street, Dublin, for an interview, at their own expense.

The appointment will be subject to approval by the Minister for Industry and Commerce.

Applications, setting out experience, and copies of references to reach the office of the undersigned not later than 5 p.m. on the 14th of December, 1949, and to be addressed to the presiding Chairman.

By Order,
T. J. SLATTERY.
Secretary.

Harbour Office,
The Square,
Tralee, Co. Kerry.

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